1983-11-01

Great Lakes Water Quality Board. Report on Great Lakes Water Quality 1983. Appendix on Radioactivity

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November 1983
Windsor, Ontario

Preface

This Appendix regarding radioactivity in the Great Lakes basin is the sixth report in a series dating from 1975 which has been submitted to the Water Quality Programs Committee and to the Great Lakes Water Quality Board. This Appendix provides information about:

1. Nuclear facilities in the Great Lakes basin and releases from these facilities.

2. Comparative releases of radioactivity from a coal-fired and a nuclear electric generating station.

3. Changes in the procedure to calculate dose from concentration data.

4. Recent changes in jurisdictional limitations for radionuclides.

5. Radioactivity data for water, fish, and the atmosphere, generated from jurisdictional programs conducted during 1981 and 1982.

6. Assessment of Great Lakes radiological quality with regard to dose to man and changes with time.

7. Remedial measures to reduce and/or prevent releases of radioactivity into the Great Lakes ecosystem.

8. Progress to develop repositories for the permanent disposal of high-level radioactive waste.

The Board has reviewed and approved this Appendix for publication.

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1. Introduction

Radionuclides can enter the Great Lakes ecosystem as a result of natural processes; via the atmospheric testing of nuclear weapons; from the use of radioisotopes in medicine, industry, and research; and from the various activities associated with the nuclear fuel cycle.

The principal natural processes which introduce radioactivity are the weathering of rocks which contain such naturally occurring radioactive minerals as uranium and thorium ores, and fallout of such cosmic-ray-produced radionuclides as ^{3}H, ^{7}Be, and ^{14}C.

The principal source of artificial radioactivity to the Great Lakes is fallout from the atmospheric testing of nuclear weapons. Beginning in July 1945, fission and fusion product radionuclides were injected into the stratosphere in increasing amounts, until a partial test ban treaty was signed in 1962. Occasional atmospheric testing has occurred since that date; the last such test was conducted in October 1980. Nonetheless, since 1964, the atmospheric inputs of radionuclides to the Great Lakes have declined sharply.

Mining of uranium-bearing ores, primarily in the Serpent River basin on the North Channel of Lake Huron, has increased the input of uranium, thorium, and radium to the Great Lakes over naturally expected levels. The source of these metals is primarily runoff from mine tailings and process waters.

The nuclear power industry began in the Great Lakes basin in 1963. The 14 nuclear generating stations consisting of 23 reactors now operating in the basin represent an installed electrical generating capacity of 15.3 GW; the current construction program calls for additional capacity of about 13.9 GW by the mid-1990's. Cooling water for each reactor is drawn from the Great Lakes and returned, contaminated with controlled amounts of radioactivity. In addition, the stations are permitted to vent radionuclides to the atmosphere, and these can enter the waters of the lake through precipitation scavenging.

In order to protect human health and the environment, the United States and Canada incorporated a specific radioactivity objective into the Great Lakes Water Quality Agreement of 1978. Since the objective is written in terms of a dose to an individual over a period of time, information about the concentration of specific radionuclides in the waters of the Great Lakes is required in order to assess compliance with the objective.

Five radionuclides in particular are considered: ^{3}H, ^{90}Sr, ^{137}Cs, ^{125}Sb, and ^{226}Ra. Their half-lives are 12.26, 29, 30, 2.7, and 1,226 years, respectively. Uranium is also of interest, not only because of its radiological properties (the half-life of ^{238}U is 4.51×10^{9} years), but also because of its chemical toxicity as a heavy metal. The first two (^{3}H and ^{90}Sr) are the major contributors to the radiological dose resulting from the ingestion of water from the Great Lakes. ^{226}Ra can also contribute a significant dose, but on a geographic site-specific basis. Doses may be

calculated, based on available jurisdictional data, using dose-to-concentration conversion factors, which have been derived in conformance with the principles established by the International Commission on Radiological Protection (ICRP).

Chapter 2 of this report summarizes the status of nuclear facilities in the Great Lakes basin, including nuclear generating stations, mines and mills, fuel fabrication and conversion facilities, and waste management facilities.

Chapter 3 tabulates releases from these facilities. The chapter also summarizes specific unplanned release events into the Great Lakes and the protocol for reporting these to the International Joint Commission.

Chapter 4 reports on a study comparing the release of radioactivity from a coal-fired electric generating station and a nuclear generating station, both of which are located in the Great Lakes basin.

Chapter 5 discusses changes to the procedure to calculate dose from concentration data, in conformance to changes introduced by the ICRP. New conversion factors are tabulated for radionuclides of interest. The chapter also discusses recent changes in jurisdictional limitations for radionuclides in water.

Chapter 6 presents data generated during 1981 and 1982 from the surveillance and monitoring programs conducted by the Great Lakes jurisdictions. The chapter provides an assessment in terms of dose to man and in terms of changes with time.

Chapter 7 describes atmospheric monitoring programs in the Great Lakes basin and tabulates the data which these programs have generated for 1981 and 1982.

Chapter 8 describes specific remedial measures implemented to reduce the release of radioactivity into the Great Lakes; special note is made of the West Valley Demonstration Project. The chapter also describes progress to develop repositories for the permanent disposal of high-level radioactive waste, as well as safety programs to ensure a high level of integrity of nuclear reactors and to improve the overall performance of the nuclear power industry as a whole.

Chapter 9 presents a summary.

2. Facilities in the Great Lakes Basin

NUCLEAR GENERATING STATIONS

Figure 1 shows the geographical locations of the 13 nuclear generating stations in the Great Lakes basin. These 14 generating stations presently have 23 reactors on line, with a total installed electrical generating capacity of 15,252 MW. Table 1 provides details regarding location, reactor type, and electrical generating capacity of each facility. Table 2 provides similar information, along with completion dates, for facilities presently under construction. Schedules for these facilities have been stretched out, with completion dates now as late as 1992. When completed, these facilities would provide an additional 13,864 MW of electrical generating capacity.

Since the last report to the Water Quality Board, in November 1981, one additional nuclear electric generator in the Great Lakes basin has come on line. On October 23, 1982, Pickering B, Unit 5 went critical and, after testing, the first electricity was generated for the grid on December 19, 1982. Pickering B, Unit 6 is presently undergoing testing, and Bruce B, Unit 1 is scheduled to start up in November 1983.

Also since the last report, plans for six additional nuclear generating stations have been cancelled:

1. Bailly - Westchester Township, Indiana.

2. Erie 1 and 2 - Erie County, Ohio. Application for construction was withdrawn.

3. Greenwood 2 and 3 - the nuclear portion of the Greenwood Energy Center, St. Clair County, Michigan.

4. Sterling - Cayuga, New York.

5. Davis-Besse, Units 2 and 3 - Ottawa County, Ohio.

6. Haven - Sheboygan, Wisconsin.

These decisions to cancel or to stretch out construction schedules have been taken for a variety of reasons which consider both costs and benefits, including:

1. Forecasts that the demand for power will grow more slowly than previously anticipated. For example, Ontario Hydro has forecast that demand will grow at an annual rate of 2.1%, down from the previous forecast of 3.0% (4).

2. The high cost of borrowing funds for construction.

Fig. 1 NUCLEAR FACILITIES IN THE GREAT LAKES BASIN

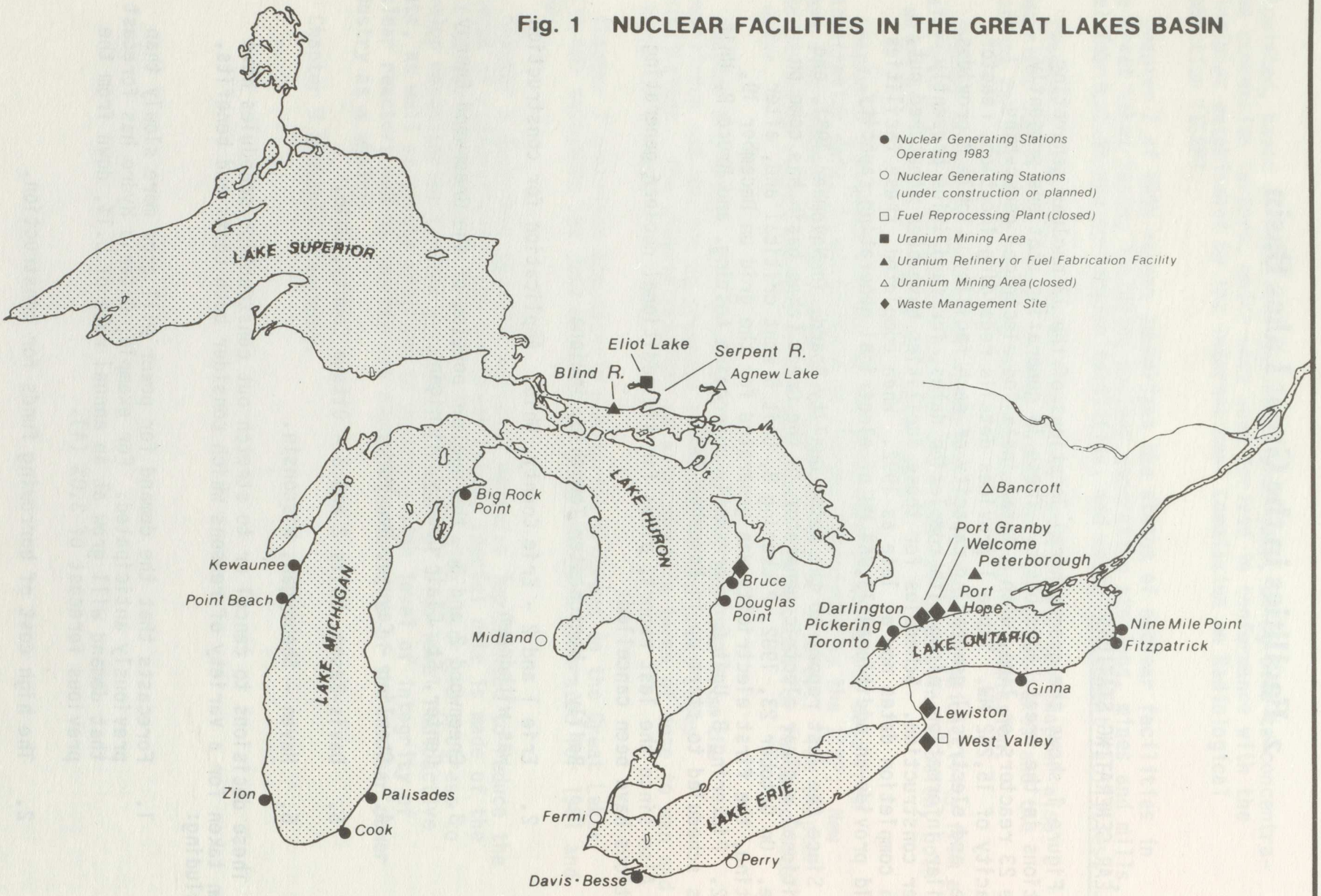

TABLE 1

OPERATING NUCLEAR GENERATING STATIONS, 1983

LAKE	STATION	LOCATION	REACTOR TYPE	ELECTRICAL POWER, MW
MICHIGAN	Zion I & II	Zion, Illinois	PWR	2 X 1040
	Kewaunee	Carlton, Wisconsin	PWR	535
	Point Beach I & II	Manitowoc County, Wisconsin	PWR	2 X 497
	Palisades	Covert Township, Michigan	PWR	805
	Big Rock Point	Charlevoix County, Michigan	BWR	72
	Cook 1 and 2	Benton Harbor, Michigan	PWR	1054 & 1060
HURON	Douglas Point	Tiverton, Ontario	CANDU	220
	Bruce A: Units 1-4	Tiverton, Ontario	CANDU	4 X 750
ERIE	Davis-Besse 1	Ottawa County, Ohio	PWR	906
ONTARIO	Pickering A: Units 1-4	Pickering, Ontario	CANDU	4 X 540
	Pickering B: Unit 5	Pickering, Ontario	CANDU	500
	Ginna	Ontario, New York	PWR	420
	Fitzpatrick	Oswego, New York	BWR	821
	Nine Mile Point 1	Oswego, New York	BWR	625

TABLE 2

NUCLEAR GENERATING STATIONS UNDER CONSTRUCTION OR PLANNED

LAKE	STATION	LOCATION	REACTOR TYPE	ELECTRICAL POWER, MW	ESTIMATED COMPLETION DATE
HURON	Midland 1 & 2	Midland, Michigan	PWR	460 & 811	1985
	Bruce B: Units 5-8	Tiverton, Ontario	CANDU	4 X 750	1984-86
ERIE	Fermi 2	Monroe County, Michigan	BWR	1093	1984
	Perry 1 & 2	Lake County, Ohio	BWR	2 X 1250	1985-88
ONTARIO	Nine Mile Point 2	Oswego, New York	BWR	1100	1986
	Pickering B: Units 6-8	Pickering, Ontario	CANDU	3 X 500	1984-5
	Darlington	Oshawa, Ontario	CANDU	4 X 850	1988-92

3. Problems associated with construction, such as quality assurance, installation and equipment deficiencies; and site problems, such as soil settlement.

4. Consideration of alternative sources for energy.

5. Environmental implications.

MINES AND MILLS

There are presently five operating uranium mines and four active mill and tailings management areas in the Great Lakes basin. All are located in the Serpent River basin of northern Ontario. Some of these facilities have been in operation for several years, while others have only recently come on line. Table 3 lists these facilities and their present operating status.

Two other mines and mills have operated in the recent past in the Great Lakes basin but are presently closed or in the process of closure and decommissioning. The Agnew Lake Mine, at Espanola, operated from 1977 to 1983, and the Madawaska Mine, at Bancroft, operated from 1957 to 1964 and again from 1976-1982.

FUEL FABRICATION AND CONVERSION FACILITIES

Table 4 lists fuel fabrication and conversion facilities in the Great Lakes basin. All are located in Ontario.

The Eldorado Mining and Refining Company began operation of a radium extraction circuit at Port Hope, Ontario in 1933. The operations by Eldorado Resources Ltd. over the past several years have included both a UO_3 refinery and a UF_6 production facility. These operations are undergoing changes which should be completed by early 1984. The present UO_3 refinery will have been shut down by the fall of 1983, and a new UF_6 facility is scheduled to commence operations in the spring of 1984. The total licensed UF_6 production capacity will increase from 5,500 to 14,500 t/a.

A new UO_3 refinery has been constructed at Blind River, Ontario and commenced operation in late 1983. The licensed capacity is 14,000 t/a.

WASTE MANAGEMENT FACILITIES

Table 5 lists waste management facilities in the Great Lakes basin and the type of waste which each handles. In addition, historic low-level radioactive wastes (soils) are presently stored at two uncontrolled sites in the Great Lakes basin (88). There are 3,200 m^3 in the City of Scarborough and 72,000 m^3 in the Town of Port Hope. These wastes are now under the jurisdiction of the Low Level Waste Management Office of Atomic Energy of Canada Ltd.

OTHER FACILITIES

Ontario Hydro is constructing a ^3H removal facility at Darlington which is scheduled to come on line in 1986-87. The plant will be able to process 350 kg of heavy water per hour. The heavy water will come from both the Pickering and the Darlington nuclear generating stations.

TABLE 3

URANIUM MINES, MILLS, AND TAILINGS MANAGEMENT FACILITIES
IN THE SERPENT RIVER BASIN[e]

FACILITY	DATES OF OPERATION
Denison Mines Ltd., Elliot Lake	
Mines and Mills:	
Main Facility	1957-Present
Stanrock	1958-1964, 1983-Present[b]
Tailings Management Areas:	
Long Lake	1959-Present
Williams Lake	1957-1959
Stanrock	1958-1964[a]
Rio Algom Ltd., Elliot Lake	
Mines, Mills, and Tailings Management	Facilities:
Panel	1958-1961, 1979-Present
Quirke	1956-1961, 1968-Present
Stanleigh	1958-1960[c], 1983-Present
Nordic	1957-1968[d]
Pronto	1955-1966
Lacnor	1957-1960[d]
Spanish American	1958-1959[d]

a. Tailings area also used by Canmet during this period.
b. All ore is milled at the Denison Main Facility.
c. Tailings area also used by Milliken Mine, 1958-1964.
d. Receive no effluent treatment.
e. Information from References (88) and (89).

TABLE 4

FUEL FABRICATION AND CONVERSION FACILITIES
IN THE GREAT LAKES BASIN

LICENSEE	OPERATION
Canadian General Electric Co. Ltd.	
Toronto	Fuel pellet manufacture. Production started in 1966. Licensed capacity - 600 Mg/a.
Peterborough	Fuel bundle manufacture. Pellets shipped from Toronto to Peterborough for assembly.
Westinghouse Canada Ltd.	
Port Hope	Fuel pellet and bundle manufacture. Production started in 1965. Licensed capacity - 750 Mg/a.
Hamilton	Research and development
Eldorado Resources Ltd.	
Port Hope	Uranium refinery and chemical conversion. UO_3 refinery to be closed in fall 1983. UF_6 capacity being expanded; to commence operation in spring 1984.
Blind River	UO_3 uranium refinery commenced operation in late 1983.

TABLE 5
RADIOACTIVE WASTE MANAGEMENT FACILITIES
IN THE GREAT LAKES BASIN[a]

LICENSEE AND LOCATION	PURPOSE
Ontario Hydro Bruce Nuclear Power Development Tiverton, Ontario Site 1	Wastes from Bruce, Douglas Point, and other Ontario Hydro nuclear generating stations. Opened 1966. In caretaking phase since November 1976, but not closed.
Ontario Hydro Bruce Nuclear Power Development Tiverton, Ontario Site 2	Waste volume reduction facility with waste compactor, radioactive and clean waste incinerators. Also trenches and tile holes for medium and low-level waste from nuclear generating stations. Opened 1975.
Eldorado Resources Ltd. Waste Management Area Port Granby, Ontario	Wastes from Eldorado refinery at Port Hope, Ontario. Opened 1955.
Eldorado Resources Ltd. Waste Management Area Welcome, Ontario	Wastes from Eldorado refinery at Port Hope, Ontario. Opened 1948. Dormant since 1960.
Agnew Lake Mines, Ltd. Espanola, Ontario	Process waters. Opened 1977, closed 1983. Work continuing to decommission heap leach pile.
Denison Mines Ltd. Elliot Lake, Ontario	Mine and mill tailings. See Table 3 for details.
Rio Algom Ltd. Elliot Lake, Ontario	Mine and mill tailings. See Table 3 for details.
Madawaska Mines Ltd. Bancroft, Ontario	Mine and mill tailings. Operated 1957-1964 and 1976-1982.
Bicroft Bancroft, Ontario	Mine and mill tailings. Operated 1958-1963
Dyno Bancroft, Ontario	Mine and mill tailings. Operated 1958-1960
Nuclear Fuel Services, Inc. West Valley, New York	Waste from U.S. atomic energy program and some from commercial processing.
Lake Ontario Ordnance Works Lewiston, New York	Refinery and conversion waste from uranium extraction operations conducted at sites inside and outside of the Great Lakes basin.

a. In addition to those listed, there are a number of abandoned tailings areas in the Elliot Lake and the Bancroft regions.

3. Releases from Facilities in 1981 and 1982

NUCLEAR GENERATING STATIONS

In the United States, two basic types of light-water-cooled reactors are used to generate electricity: the pressurized-water reactor (PWR) which operates on an indirect cycle, and the boiling water reactor, which operates on a direct cycle. Both utilize uranium, enriched to 2-4% in the ^{235}U isotope, as the fuel. In Canada, CANDU reactors use natural uranium (0.72% ^{235}U) as the fuel. Heavy water (deuterium oxide) is used as moderator and as primary coolant.

The nuclear power plants produce highly radioactive atoms (fission products) from the fission of the uranium atoms and also from the absorption of neutrons by the non-radioactive coolant and by the structural materials (activation products). The more important radionuclides produced by uranium fissioning are isotopes of the noble gases krypton and xenon, the alkali metals cesium and rubidium, the alkaline earths barium and strontium, and the halogens iodine and bromine. The radioactive coolant activation products are generally gases such as tritium, argon, fluorine, nitrogen, and oxygen; these generally have short half-lives.

The induced activities in the structural materials may have considerably longer half-lives and comprise a much wider range of radioactive elements including zirconium, manganese, nickel, iron, carbon, chromium, cobalt, and copper.

For United States reactors, the most important radioisotopes are tritium, cobalt, strontium, and cesium. For Canadian reactors, the most important is tritium.

The small fraction of radionuclides produced by activation and fission are released in a controlled manner. Aqueous releases are mixed with the cooling water discharge, and gaseous releases are vented to the atmosphere.

As a condition of their operating licenses, nuclear generating stations are required to monitor and report these gaseous and aqueous releases to the responsible federal regulatory agency. Total annual releases from nuclear generating stations in 1981 and 1982 are summarized in Table 6. At Canadian stations, these releases are generally less than 1% of the derived emission limit (Table 7).

Some data for the Point Beach station were not yet available when the 1980 release information was reported to the Water Quality Board. Gaseous discharges from the Point Beach 1 and 2 station for 1980 were: particulates - 0.0003 Ci; ^{131}I - 0.0009 Ci; noble gases - 641 Ci; and ^{3}H - 653 Ci. For

TABLE 6

DISCHARGES FROM NUCLEAR GENERATION STATIONS[b]

STATION	ANNUAL RELEASE IN CURIES					
	GASEOUS				AQUEOUS	
	PARTICULATES	^{131}I	NOBLE GASES	^{3}H	FISSION AND ACTIVATION PRODUCTS	^{3}H
			1981			
Big Rock Point	0.004	0.002	17,900	10.22	0.39	3.1
Bruce A	0.0025	0.0028	16,000	92,000	2.2	20,000
Cook 1 & 2	0.278	0.037	5,421	5.47	1.87	916
Davis-Besse 1	0.004	0.054	1,012	8.65	0.79	157
Douglas Point	0.00098	0.12	32,000	11,000	0.2	2,200
Fitzpatrick	0.165	0.115	119,500	6.65	2.51	4.1
Ginna	0.00001	0.001	546	70.1	0.04	240
Kewaunee	0.00003	0.00009	118	4.01	0.82	251
Nine Mile Point 1	0.008	0.006	611	63.4	5.35	5.1
Palisades	0.001	0.040	3,002	6.42	0.03	278
Pickering	0.0046	0.0017	6,800	16,000	0.21	7,500
Point Beach 1 & 2	0.0004	0.004	611	480	1.09	652
Zion 1 & 2	0.008	0.005	6,910	a	2.65	870
			1982			
Big Rock Point	0.002	0.003	12,930	6.26	0.26	2.98
Bruce A0.0024	0.024	0.032	14,000	41,000	2.1	26,000
Cook 1 & 2	0.024	0.104	3,883	5.11	1.90	1,295
Davis-Besse 1	0.00003	0.005	535	35.5	0.22	57
Douglas Point	0.00045	0.092	62,000	8,600	0.50	3,300
Fitzpatrick	0.337	0.434	211,000	5.26	0.65	0.65
Ginna	0.0002	0.0008	1,955	96.6	0.62	308
Kewaunee	0.00003	0.00003	166	8.07	1.52	318
Nine Mile Point 1	0.071	0.020	51.1	53.5	0.003	5.82
Palisades	0.004	0.023	7,382	4.49	0.127	179
Pickering	0.0027	0.0019	6,600	18,000	0.49	10,000
Point Beach 1 & 2	0.0002	0.008	993	1,017	2.95	503
Zion 1 & 2	0.082	0.007	16,090	a	5.25	90,753

a. Not available.
b. Information from References (1) and (2).

TABLE 7

RELEASES FROM NUCLEAR GENERATION STATIONS AS A PERCENTAGE OF THE DERIVED EMISSION LIMIT[a]

STATION AND YEAR	PERCENTAGE OF DERIVED EMISSION LIMIT					
	GASEOUS				AQUEOUS	
	PARTICULATES	^{131}I	NOBLE GASES	^{3}H	FISSION AND ACTIVATION PRODUCTS	^{3}H
Bruce "A"						
1981	0.0012	0.0031	0.74	0.88	0.29	0.14
1982	0.0011	0.037	0.61	0.39	0.28	0.18
Douglas Point						
1981	0.00026	0.076	0.41	0.028	0.37	0.23
1982	0.00012	0.059	0.80	0.021	0.93	0.33
Pickering						
1981	0.0089	0.0083	0.29	0.15	0.023	0.045
1982	0.0051	0.0089	0.28	0.18	0.055	0.060

a. Information from Reference (2).

the Zion 1 and 2 station, the amount of ^{3}H released to the atmosphere during 1980 was also not available at the time of publication. ^{3}H was subsequently reported to be not detected (1).

MINES AND MILLS

Effluent discharges from tailings management areas in the Serpent River basin are given in Table 8 for the years 1979, 1980, and 1981. It should be noted that the total releases reported here for 1979 and 1980 for dissolved ^{226}Ra and for uranium are considerably lower than the releases reported previously (3). This may be due in part to the method of calculation or the types of releases reported. For example, the data in Table 8 are only effluent discharges from tailings management areas. The data reported previously may have covered other types of releases as well, e.g. untreated releases.

FUEL FABRICATION AND CONVERSION FACILITIES (2)

The loading of uranium to Lake Ontario from the UO_3 refinery, operated by Eldorado Resources Ltd., at Port Hope is 0.82 kg/d. The UF_6 production facility releases 0.15 kg/d of uranium. UO_3 refinery operations at Port Hope were to cease in 1983, and the UF_6 capacity expanded by 1984. The release of uranium from the new UF_6 has been estimated to be 0.36 kg/d.

Table 9 presents averaged quarterly results of ^{226}Ra concentrations in plant water effluent at the Port Hope refinery. If an average flow rate of 5.0 m^3/minute and an operational basis of 340 days/year are assumed, then the annual loadings of ^{226}Ra from this facility are estimated to be 2.69 and 5.51 mCi for 1981 and 1982, respectively. This compares with releases of 0.73 and 2.20 mCi, calculated for 1979 and 1980, respectively (3).

Eldorado Resources is constructing a new UO_3 refinery at Blind River. The uranium emission to the North Channel has been estimated to be 0.36 kg/d.

The aqueous release of uranium dioxide from the Westinghouse Canada fuel plant in Port Hope during 1982 was estimated to be 3.6 kg. This assumes that the plant operated for 250 days during the year. Data were not available to calculate the 1981 releases; however, since a new waste treatment facility was commissioned during that year, the quantity released in 1981 would be expected to have been somewhat greater than in 1982. The airborne releases of uranium dioxide from the Westinghouse facility were estimated to be 387 and 77 g in 1981 and 1982, respectively. The quantity released in 1982 was less than in 1981, because improvements to the dust extraction system increased its effectiveness.

Canadian General Electric operates fuel fabrication facilities at Toronto and at Peterborough. Uranium is released into the water effluents as a result of washing the floor and walls in those areas where UO_2 is processed. The estimated annual release of uranium from the Toronto and the Peterborough facilities are estimated to be 158 kg and 7 g, respectively. These estimates assume annual average concentrations of 79 and 8.5 mg/L, respectively, and total discharge volumes of 2×10^6 and 810 L, respectively. Release levels are about the same for both 1981 and 1982.

TABLE 8

EFFLUENT DISCHARGES FROM TAILINGS MANAGEMENT AREAS IN THE SERPENT RIVER BASIN[b,c]

FACILITY	YEAR	AVERAGE DISCHARGE (L/s)	DISSOLVED ^{226}Ra		TOTAL ^{226}Ra		URANIUM	
			AVERAGE CONCENTRATION (Bq/L)	ANNUAL LOADING[a] (mCi)	AVERAGE CONCENTRATION (Bq/L)	ANNUAL LOADING[a] (mCi)	AVERAGE CONCENTRATION (µg/L)	ANNUAL LOADING[a] (kg)
Long Lake	1979	267	0.07	15.9	0.8	181.9	-	-
	1980	210	0.09	16.1	0.73	130.5	-	-
	1981	263	0.12	26.9	1.13	253.0	-	-
Williams Lake	1979	15.6	0.13	1.7	0.25	3.3	-	-
	1980	6.8	0.13	0.8	0.22	1.3	-	-
	1981	9.2	0.38	3.0	0.51	4.0	-	-
Stanrock	1979	67.5	0.03	1.7	0.05	2.9	-	-
	1980	69.8	0.03	1 8	0.03	1.8	-	-
	1981	59.5	-	-	0.03	1.5	-	-
Panel	1980	96	0.13	10.6	0.37	30.2	80	242.2
	1981	81	0.11	7.6	0.39	26.9	118	301.4
Quirke	1979	369	0.22	69.1	2.9	911.2	143	1664.1
	1980	317	0.25	67.5	3.1	836.7	254	2539.2
	1981	258	0.21	46.1	2.42	531.6	156	1269.3
Stanleigh	1979	405	0.35	120.7	-	-	-	-
	1980	246	0.28	58.6	-	-	-	-
	1981	201	0.3	51.3	-	-	12.8	81.1
Nordic	1979	91.6	0.14	10.9	-	-	-	-
	1980	55.4	0.08	3.8	-	-	28	48.9
	1981	53.2	0.09	4.1	-	-	67.9	113.9
Pronto	1979	88.3	0.21	15.8	-	-	-	-
	1980	72.5	0.16	9.9	-	-	23.7	54.2
	1981	60.3	0.12	6.2	-	-	34.0	64.7
Total Annual Loading	1979			235.8		1099.3		1664.1
	1980			169.1		1000.5		2884.5
	1981			145.2		817.0		1830.4

a. Annual loading for each facility calculated by multiplying the average discharge volume by the average concentration.
b. Summary of effluent quality for tailings effluent treatment facilities.
c. Information from Reference (2).

TABLE 9

^{226}Ra IN WATER EFFLUENT FROM
ELDORADO RESOURCES LIMITED FACILITIES AT PORT HOPE[a,b]

QUARTERLY AVERAGE	CONCENTRATION, pCi/L	
	1981	1982
1st	1.3	4.2
2nd	<1.0	4.2
3rd	<1.0	1.3
4th	1.1	2.0
ANNUAL	1.10	2.25

a. Average effluent flow rate is 4.5 m^3/minute.
b. Information from Reference (2).

TABLE 10

WELCOME AND PORT GRANBY SAMPLING DATA - 1981 and 1982[b]

LOCATION	YEAR	FLOW (10^6L/a)	RADIUM		URANIUM	
			Average Conc.[a] (pCi/L)	Annual Loading (mCi)	Average Conc.[a] (mg/L)	Annual Loading (kg)
Port Granby	1981	83[a]	2.9	0.2	0.26	22
Stream Water	1982	-	5	-	0.66	-
Welcome	1981	71.8	2.6	0.2	0.64	46
Treatment Plant	1982	81.7	3	0.2	-	-

a. Calculated from mean monthly values.
b. Information from Reference (2).

Airborne releases from the Toronto and the Peterborough facilities have been estimated to be 157 and 1 g, respectively. As for the aqueous releases, levels are about the same for both 1981 and 1982.

WASTE MANAGEMENT FACILITIES (2)

Wastes from the Eldorado Resources Ltd. refinery are presently stored in near-surface, in-ground burial facilities near Welcome and Port Granby, Ontario. The operating licenses for these two facilities specify effluent discharge limits of 0.37 Bq/L (10.0 pCi/L) for dissolved and suspended ^{226}Ra and 0.5 mg/L for As.

Releases of radium and uranium from the Welcome and Port Granby facilities for 1981 and 1982 are summarized in Table 10. The annual loading of radium from each facility was about 0.2 mCi. The annual loading of uranium from each facility in 1981 was 46 and 22 kg, respectively.

UNPLANNED RELEASES

Reportable Events

United States

Part 20 of the U.S. Nuclear Regulatory Commission (NRC) regulations deals with standards for protection against radiation, and Part 50 addresses domestic licensing of production and utilization facilities.

Operators of nuclear power plants, by the technical specifications to their operating license and by sections of Part 20 and Part 50 of the U.S. NRC regulations, are required to report to the U.S. NRC whenever specific events occur. These Licensee Event Reports (LER's) are technical descriptions of operational events; they provide the basis for the careful study of events that might be precursors to serious accidents.

In order to more effectively collect and evaluate this information, and especially as a result of the accident at Three Mile Island, changes have been implemented on a continuing basis to improve the timeliness, accuracy, and clarity of information transmitted between licensees and the U.S. NRC, following accidents or other significant events at operating nuclear power plants.

To better achieve these goals, the U.S. NRC will further amend Part 50 of its regulations, effective January 1, 1984 (5). The LER's will require a clear narrative describing an event, including the cause, plant status before the event, and the sequence of major occurrences during the event. Also, the LER will include the licensee's assessment of the potential and actual safety consequences of the event.

Regarding the release of radioactivity to the environment, events reportable to the U.S. NRC include:

1. Any airborne radioactivity release that exceeds two times the applicable concentrations of the limits specified in the U.S. NRC regulations for unrestricted areas, when averaged over a time period of one hour.

2. Any liquid effluent release that exceeds two times the limiting combined maximum permissible concentration at the point of entry into the receiving water in an unrestricted area for all radionuclides except ^{3}H and dissolved noble gases, when averaged over a time period of one hour.

The effluent release reporting requirements of Part 20 of the U.S. NRC regulations must also be met; as well, other operational events which meet the criteria in Part 50 must be reported.

Unplanned releases from nuclear generating stations in the United States are reported promptly by the licensee to the U.S. NRC duty officer in Bethesda, Maryland. The information is provided in a daily report, which is available throughout the U.S. NRC. For releases which do not exceed U.S. NRC requirements, further publicity is not warranted. Also, because of the small quantity of radioactivity which might be involved, such releases are not specifically reported to the International Joint Commission. For unplanned releases which exceed U.S. NRC requirements, or which could affect human health or the environment, the information is made public through the media and other appropriate means.

All releases, whether planned or unplanned, are reported in the facility's semi-annual effluent report to the U.S. NRC. These totals are reported to the International Joint Commission on an annual basis (see Table 6), but the portion attributable to unplanned releases is not identified as such.

Canada

In Canada, information about unplanned releases is reported by the utility to the Atomic Energy Control Board (AECB). The information is in turn provided to the International Joint Commission by a representative of the AECB with regard to:

1. Nuclear power plants exceeding their operating target of 1% of the derived release limit, calculated on a weekly or a monthly basis;

2. Other AECB licensees exceeding any operating targets contained in their license conditions; or

3. Any occurrence of a lesser release (either atmospheric or aqueous) to the Great Lakes or its tributaries which has a perceived public interest, such as when the AECB or the licensee plans to issue a press release describing the occurrence.

As in the United States, the quantity of radioactivity released via unplanned events is included in the total release reported for each facility; these totals are reported annually to the International Joint Commission (see Tables 6 and 7).

Specific Release Events

Summarized below, for 1981, 1982, and the first nine months of 1983, are those events reported to the International Joint Commission which resulted in the unplanned release of radioactivity to the environment from facilities in the Great Lakes basin. For most of these releases, license conditions and operating targets were not exceeded, and there was no threat posed to human health and the environment. Although for one release event to the water, the operating target for the facility was exceeded, there was nonetheless no basis for any environmental or human health concern.

Unplanned release events are briefly summarized below. Events which did not result in the release of radioactivity are not discussed.

Ginna Nuclear Power Plant, Ontario, New York (6-11)

On January 25, 1982 one of the more than 3,000 small tubes which carry superheated radioactive water from the primary cooling system through the steam generator, ruptured. Thus, the water from the primary system intermingled with steam in the secondary system, which drives the turbines of the electric power generators. Pressure dropped in the primary system and increased in the secondary system. This resulted in a release of radioactive steam into the air and the spilling of mildly radioactive water onto the floor of the reactor containment building. The reactor was stopped and the plant shut down within minutes. Cold shutdown was achieved by the afternoon of January 26.

The release of radioactive steam continued for about 2 hours and was halted by the closing of a pressure release valve. The U.S. NRC's preliminary estimate was that about 500 Ci was released in the form of noble gases. Field survey teams reported that actual atmospheric radiation readings at the time of the release were within safe limits even at the plant boundaries. The highest reading recorded was 3 millirad per hour and, less than one-half mile away, readings were at levels attributable to natural background radiation. Radiation levels outside the building were about 1 millirad per hour; however, within hours, levels were down to the normal background values.

The U.S. NRC concluded that the maximum dose a person outside the plant might have received was about 15 mrem. For comparison, the dose from a medical x-ray is in the range of 20-100 mrem.

About 43,000 L (11,000 gallons) of mildly radioactive water spilled onto the floor of the containment building, but none was released to the environment. The water was subsequently removed to a holding tank, prior to evaporation and solidification of the radioactive residue, which would be disposed of according to the established procedure.

The cause of the rupture was initially attributed to corrosion, but subsequent investigation attributed it to poor workmanship and sloppy maintenance. Inspection of the facility found a piece of boiler plate metal, two long sections of severed tubing, and several other small pieces of metal in the steam generator, apparently left in the vessel by workmen when repairs were made in 1975. Apparently the fast flowing water and steam tossed the metal pieces about, knocked them against the small tubes, and eventually caused the rupture.

Details of the U.S. NRC investigation have been published (12).

Bruce Nuclear Power Development, Ontario (13-16)

On May 4, 1981, while Unit 3 was being returned to service, approximately 400 kg of deuterium oxide was spilled on the floor of the generating station; the concentration of tritium was 1 Ci/kg. A fraction of the spilled liquid got out of the building through the seals of a door. About 50% of the spilled liquid was eventually recovered. The only significant radioactivity measured was that due to tritium; the estimated maximum amount released to the environment was 400-500 Ci. There is a strong possibility that a fraction of this amount eventually reached Lake Huron, as a result of rain, which came immediately after the spill. The derived emission limit for the Bruce facility is 1.4×10^6 Ci/month. The impact on the lake as a result of this spill is insignificant.

August 29, 1981, 3,000 L of deuterium oxide were drained into a sump. During the following week, approximately 850 L of water, containing approximately 8,000 Ci of tritium, evaporated and entered the outside atmosphere through a filtered exhaust stack. The release was 4% of the derived emission limit of 200,000 Ci per week. The target, under normal operating conditions, is 1% or 2,000 Ci per week. Monthly tritium measurements around the facility were not unusually high during August and September 1981. To prevent a recurrence of such a large release, air driers are being installed and other preventative measures are being taken.

On September 20, 1981, a ruptured disc burst during transfer operations from nuclear boilers to storage tanks; 19 tonnes of water containing tritium spilled. The spill was attributed to operator error.

Douglas Point, Ontario (16, 17, 68, 91)

Between July 17 and 19, 1981, 100 to 200 kg of deuterium oxide containing 15 TBq (405 Ci) of tritium escaped from the heat exchangers and entered Lake Huron. This release was about 0.5% of the derived release limit (DRL) for tritium in water. Drinking water samples were collected daily at Kincardine and Port Elgin and analyzed for tritium. All results were below the detection limit of 20 Bq/L (540 pCi/L).

On May 2, 1983, a leak occurred during the transfer of deuterium oxide from the heat transport system to a holding tank; 1.2 tonnes escaped. Most entered an inactive sewer, but some evaporated. The estimate of the quantity lost was 5%. The contamination level was 2 Ci of tritium per kilogram of deuterium oxide. The total potential release of tritium to the environment

was 120 Ci. The DRL for airborne releases from the Bruce site, which includes the Douglas Point facility is 800,000 Ci per week and, for waterborne releases, 80,000 Ci per month. The unplanned release was less than 1% of the DRL.

On September 5, 1983, an estimated 3.2 tonnes of deuterium oxide entered Lake Huron as a result of a leak from the primary heat transport system into the cooling water. The duration of the leak was 90 minutes. An estimated 6,000 Ci of tritium reached the lake; this was about 7% of the monthly DRL for tritium in water.

Pickering Nuclear Generating Station, Ontario (69, 91)

On August 4, 1983, a leak occurred in a heat exchanger in Unit 1 of the Pickering Nuclear Generating Station. The leak continued for about seven hours. Deuterium oxide containing approximately 250 Ci of tritium was released to Lake Ontario. The monthly DRL is 1.4×10^6 Ci.

On August 1, 1983, Unit 2 shut down when a major loss of coolant occurred through a rupture in one of the coolant tubes. The coolant was completely contained inside the reactor building; there was no direct release of deuterium oxide or of tritium to Lake Ontario.

On September 4, 1983, an estimated two tonnes of deuterium oxide entered Lake Ontario as a result of a heat exchanger leak at Unit 5. An estimated 600 Ci reached the lake.

Eldorado Resources Limited, Port Hope, Ontario (11, 16, 18-20, 87)

From December 1980 to April 1981, the reported uranium levels in dustfall in the vicinity of the Eldorado Resources refinery were generally four to five times the normal level, with a maximum observed value of about 100 times the normal level. The estimated air concentration exceeded 1 $\mu g/m^3$. The problem was traced to a faulty baghouse filter and subsequently corrected.

On January 29, 1982, a corroded valve caused 115 L of acid, used to process uranium at the UO_3 plant, to slip into the steam system. As a result, for about four days following the spill, the average uranium concentration in the harbour was 2.3 mg/L. This concentration is about four times the limit (0.5 mg/L) allowed in the facility's operating license for the discharge of cooling water to the harbour. For comparison, for the period 1979-1982, the average concentration of uranium in water from the harbour was 0.18 mg/L; this value was reported by Eldorado Resources Limited, as a result of monitoring the water intake at the refinery. The maximum acceptable concentration for uranium in drinking water is 0.02 mg/L, established by the Department of National Health and Welfare (26). The Canada Department of the Environment reported that none of the resulting contamination entered the Port Hope drinking water supply.

On December 21, 1982 a fire occurred at the UF_6 plant. The water used to put out the fire carried uranium to the harbour. A maximum concentration of 60 mg/L was reported; this decreased to 7 mg/L after two hours. The maximum acceptable concentration for uranium in drinking water, averaged over a period of one year, is 0.02 mg/L and the objective $\leq$0.001 mg/L. The Port Hope drinking water supply was monitored, but no increase in uranium level was observed.

On January 13, 1983 a leak occurred in the heat exchanger of the raffinate evaporator, at the UO_2-UO_3 North Plant. Condensate was diverted to a drain system, and was ultimately discharged to Port Hope Harbour. Six hours after the leak began, the concentration of uranium at the outfall was reported to be about 0.12 to 0.14 mg/L and, in the West Slip of the Harbour, about 0.06 mg/L; the pH at the outfall was reported to be 1.5. On subsequent days, January 21-28, the concentration in the harbour was 0.04 mg/L. The duration of the leak was 3.5 hours. About 40 L of raffinate was lost.

In early 1982, the Atomic Energy Control Board renewed the operating license for the refinery. Eldorado was directed to submit a firm schedule for completing requirements concerning monitoring of emissions, to make further efforts to identify remaining sources of emissions, and to conduct a detailed plant inspection to identify potential trouble spots.

Canadian General Electric, Toronto (21)

An incorrectly filtered discharge vent resulted in the release of small quantities of radioactive thorium from a Canadian General Electric plant in Toronto onto a parking lot outside the plant. Levels of radioactivity did not exceed federal (Atomic Energy Control Board) standards. However, the Ontario Ministry of the Environment was concerned about the powdery substance becoming loose or mobile and, therefore, requested a thorough cleaning of potentially contaminated surfaces; this cleaning has been completed. The company now sends its thorium wastes and cleaning cloths to the federal facility for management of low-level radioactive wastes, at Chalk River, Ontario.

Thorium is used in the production of lamp coils.

4. Radioactivity from Coal-Fired and Nuclear Electric Generating Plants

BACKGROUND AND CONCEPT OF STUDY

In addition to nuclear facilities, there are a number of fossil-fuel electric generating stations along the shores of the Great Lakes. Most of these consume coal which contains traces of the uranium and thorium decay series and of ^{40}K. During the combustion of coal, these radionuclides become concentrated in the fly ash, some of which escapes pollution control equipment and enters the atmosphere. Furthermore, all of the radon gas trapped within the coal is released to the atmosphere. The disposal of waste ash from the thermal stations may also constitute a radiological problem, since the ash contains radionuclides at concentrations several times higher than those in normal soils.

Published reports (22, 23) have indicated that naturally occurring radionuclides released in the combustion of coal may be comparable to the routine emissions from a nuclear electric generating station. In order to determine health impacts from radionuclides associated with electric power generation, the Canada Department of National Health and Welfare investigated radionuclide releases from the Nanticoke coal-fired electric generating station on Lake Erie and from the Pickering nuclear generating station on Lake Ontario. Studies were conducted during 1979 through 1981 (16, 24-25).

The major pathways for human exposure are inhalation of radionuclides in the air, and ingestion of radionuclides in food and water. In order to determine radionuclide concentrations and exposure via various environmental routes, analyses were performed on feed coal, fly ash, and bottom ash samples collected from the Nanticoke station; air, precipition, soil, and vegetation samples from the vicinity of both stations; and ash and water samples from the storage lagoon at Nanticoke and from the Booth disposal pit near Toronto. This latter pit receives ash mainly from the Lakeview thermal generating station.

The study was also designed to differentiate among radionuclides from sources other than the two generating stations.

A more detailed description of the program, including sampling and analytical procedures, has been published (24). The findings presented below are from reports published by the Department of National Health and Welfare (16, 24-25).

RESULTS

Feed Coal, Fly Ash, And Bottom Ash

Analyses of feed coal, fly ash, and bottom ash are summarized in Table 11. Radionuclide concentrations in the ash are generally enriched by a factor of 7 to 8 with respect to coal. There is little difference between fly and bottom ash.

TABLE 11

RADIONUCLIDES IN NANTICOKE FEED COAL AND ASH

NUCLIDE	CONTENT			ENRICHMENT FACTOR OVER COAL	
	COAL	FLY ASH	BOTTOM ASH	FLY ASH	BOTTOM ASH
^{40}K (Bq/kg)	26.4±0.6	204±4	245±4	7.7±0.2	9.3±0.3
^{226}Ra (Bq/kg)	12.4±0.3	92±3	91±3	7.4±0.3	7.4±0.3
^{228}Ra (Bq/kg)	7.5±0.2	58±2	61±2	7.7±0.3	8.1±0.3
U (mg/kg)	1.01±0.02	7.5±0.2	7.4±0.2	7.4±0.3	7.4±0.3
Th (mg/kg)	1.85±0.04	14.1±0.5	15.0±0.5	7.7±0.3	8.1±0.3

Conversion factor: 1 Bq = 27pCi

TABLE 12

RADIONUCLIDE CONTENT IN SIFTED FRACTIONS OF ASH SAMPLE
(Bq/kg)

MESH SIZE (μm)	^{40}K	^{226}Ra	^{228}Ra
<20	433±20	117±6	85±5
20-32	440±20	126±2	99±4
32-48	441±22	124±8	93±3
48-100	437±21	123±3	85±8
100-200	617±13	142±5	-
200-400	507±29	155±4	101±4
>400	544±28	170±4	106±10

Conversion factor: 1 Bq = 27 pCi

The concentrations of ^{210}Pb and ^{226}Ra in water samples from the ash storage lagoon at Nanticoke and the disposal pit at Toronto were generally below the detection limit of 0.27 pCi/L. Leaching of these radionuclides from the ash was negligible, hence, ground and surface water were not being contaminated by them.

Dissolved ^{222}Rn in the water was only about 2.7 pCi/L, which would preclude a large-scale emanation of radon from the ash.

The concentration of uranium in lagoon water samples was 1 to 2 µg/L. This is within the maximum acceptable concentration of 20 µg/L for a drinking water supply (26).

To determine if there was any dependence of radionuclide concentration on particle size, analyses were performed on sifted ash fractions. The results of one such analysis (Table 12) indicate a trend of increasing concentration of ^{226}Ra and ^{228}Ra on finer particles. Since it is the finer particles which are most likely to be resuspended by water and wind, these could be deposited in the lungs if subsequently inhaled.

Soil

Results of analyses of soil samples (Table 13) show that ^{7}Be, ^{125}Sb, ^{137}Cs, and ^{144}Ce are deposited on the surface of the soil; only ^{137}Cs was found at a depth greater than 5 cm. The naturally occurring radionuclides ^{40}K, ^{226}Ra, and ^{228}Ra appeared to be uniformly distributed throughout the upper 15 cm of soil, indicating that they are native to the soil rather than the result of surface deposition. All radionuclide concentrations appeared somewhat higher at Nanticoke than at Pickering, but this could be a general feature of the Nanticoke area.

Air and Precipitation

Results of analyses of air filters are summarized in Table 14. More than 98% of the activity arises from ^{7}Be and ^{210}Pb, with the remainder coming from ^{40}K and long-lived fission produces.

^{7}Be is produced by cosmic ray bombardment in the upper atmosphere and carried by air movements to ground level. Concentrations are comparable to gross ß activities recorded for Ontario in general (24).

Enhancement of naturally occurring radionuclides such as ^{210}Pb and ^{40}K in air samples collected in the vicinity of the Nanticoke station would indicate a possible contribution from coal combustion. However, apart from a slight excess of ^{210}Pb, no trends were apparent. The major sources of ^{210}Pb are from the decay of radon gas emanating from the soil and from the combustion of coal. ^{40}K is measurable only in the summer and early fall, when dry conditions are conducive to suspension of soil particles.

An enhancement of long-lived fission products, such as ^{106}Ru, ^{125}Sb, and ^{137}Cs in air samples collected in the vicinity of the Pickering station would indicate a possible contribution from nuclear reactors. However, analysis of the air filters collected near Pickering showed no enhancement of

TABLE 13

RADIONUCLIDE CONCENTRATIONS IN SOILS NEAR GENERATING STATIONS[a,c]
(Bq/kg)

NUCLIDE	PICKERING NUCLEAR GENERATING STATION		NANTICOKE THERMAL GENERATING STATION	
	5 km E	11 km E	5 km NNE	10 km NNE
^{7}Be	b	10±2	54±12	18±9
	b	b	b	b
^{40}K	622±6	505±5	762±10	839±8
	644±7	520±5	709±7	832±7
^{125}Sb	b	1.0±0.3	5.1±0.80	b
	b	b	b	b
^{137}Cs	15.3±0.3	13.2±0.3	40.4±0.6	32.9±0.4
	7.4±0.3	3.8±0.2	8.2±0.30	17.0±0.3
^{144}Ce	1.8±0.7	3.0±0.6	14.0±1.5	b
	b	b	b	b
^{226}Ra	26.1±1.0	21.4±1.0	20±3	34.1±1.7
	20.1±1.0	23.7±0.7	28±2	35.8±0.9
^{228}Ra	24.5±0.7	17.9±0.5	41.6±1.2	43±2
	25.6±1.2	20.5±0.5	34.8±1.3	44.2±1.2

a. Upper values correspond to the upper 2" of soil, and lower values correspond to 2" - 6" depth of soil.

b. Not detected.

c. Conversion factor: 1 Bq = 27pCi.

TABLE 14

SUMMARY OF RADIONUCLIDE CONCENTRATIONS[a,c]
IN AIR AT NANTICOKE AND PICKERING
($\mu Bq/m^3$)

RADIONUCLIDE	LOCATION	1979	1980			
		OCT. TO DEC.	JAN. TO MARCH	APR. TO JUNE	JULY TO SEPT.	OCT. TO DEC.
^{7}Be	Nanticoke	2814	3980	4270	3490	3460
	Pickering	2030	3300	3380	3110	3050
^{40}K	Nanticoke	b	b	b	63.8	35.0
	Pickering	b	b	b	27.0	39.3
^{106}Ru	Nanticoke	3.0	3.5	13.7	3.4	b
	Pickering	8.6	7.5	15.1	6.7	b
^{125}Sb	Nanticoke	4.4	2.5	8.1	2.4	b
	Pickering	b	b	6.6	1.2	b
^{137}Cs	Nanticoke	6.3	8.7	23.4	17.4	6.1
	Pickering	5.4	7.7	15.6	12.7	5.1
^{144}Ce	Nanticoke	9.7	12.4	27.5	16.8	56.6
	Pickering	4.4	7.1	16.6	10.7	9.1
^{210}Pb	Nanticoke	931	775	378	806	502
	Pickering	466	456	303	709	620

a. Precision is ± 30% for ^{106}Ru, ^{125}Sb, and ^{144}Ce and ± 10% for the others (68% confidence limits).
b. Not detected.
c. Conversion factor: 1 Bq = 27pCi.

fission product activities relative to those from the Nanticoke area. The traces of long-lived fission products observed are generally associated with worldwide fallout from nuclear weapons testing. The high value of ^{144}Ce recorded in late 1980 may be associated with the atmospheric weapons test conducted on October 16, 1980.

The studies also showed that the concentrations of ^{137}Cs and ^{210}Pb around Nanticoke are not significantly enhanced at downwind sites.

Radiochemical analyses carried out on air filter and precipitation samples for ^{226}Ra and for total uranium showed no apparent trends at Nanticoke that could be attributed to emissions from the coal-fired station. Concentrations ranged from 1.9 to 5.4 x 10^{-5} pCi/m^3, with a mean of 3.0 ± 0.54 x 10^{-5} pCi/m^3. The mean value recorded for the Pickering area was 1.6 ± 0.8 x 10^{-5} pCi/m^3. Average monthly ^{226}Ra depositions at two sites in the Nanticoke area were 5.9 ± 1.3 pCi/m^2.month and 14.0 ± 6.8 pCi/m^2.month, comparable to a mean value of 6.5 pCi/m^2.month at New York City (27).

Vegetation

Produce samples from the Nanticoke area showed minute traces of ^{7}Be and ^{137}Cs.

DOSE TO MAN

The Department of National Health and Welfare estimated (16) a dose equivalent of 0.01 mrem/a (0.1 µSv/a), due to inhalation, for an individual who lives at the position of maximum ground level concentration at 10 km east of the plant. An individual who consumes food grown entirely in the plant vicinity could receive a dose equivalent of 0.027 mrem/a (0.27 µSv/a). These are extremely low compared to an estimated dose of 3 mrem/a (30 µSv/a) at the site boundary of the Pickering Nuclear Generating Station (90), or to the dose of 200 mrem/a (2,000 µSv/a) from normal background radiation.

5. Objectives, Standards, and Criteria

Measurements of radioactivity in the Great Lakes basin are in terms of concentration, whereas the Agreement objective is in terms of dose to man. This chapter describes recent changes in the conversion factors between the two.

The Great Lakes jurisdictions have established limitations for the concentrations of radionuclides in drinking water. Comparison of observed concentrations with these limitations, as well as with the Agreement objective provides a measure of the status of the Great Lakes with regard to radioactivity, and identifies areas where corrective measures may be required. This chapter also describes recent changes in drinking water limitations and tabulates the present values for the Great Lakes jurisdictions.

AGREEMENT OBJECTIVE

The specific radioactivity objective for the Great Lakes is given in Annex 1 of the 1978 Great Lakes Water Quality Agreement:

> The level of radioactivity in waters outside of any defined source control area should not result in a TED_{50} (total equivalent dose integrated over 50 years as calculated in accordance with the methodology established by the International Commission on Radiological Protection) greater than 1 millirem to the whole body from a daily ingestion of 2.2 litres of lake water for one year. For dose commitments between 1 and 5 millirem at the periphery of the source control area, source investigation and corrective action are recommended if releases are not as low as reasonably achievable. For dose commitments greater than 5 millirem, the responsible regulatory authorities shall determine appropriate corrective action.

The objective was developed to protect public health and the environment. It considers both ambient water quality and control of release of radioactive materials.

CONCENTRATION-TO-DOSE CONVERSION FACTORS

The objective is expressed in terms of a total equivalent dose to an individual over a period of 50 years. The dose can be calculated from measured concentration values, using appropriate conversion factors for each radionuclide of interest.

In 1977, the International Commission on Radiological Protection (ICRP) published (28) a set of new recommendations which changed the way in which the dose to a particular organ or tissue is related to the dose to the whole body. The ICRP philosophy has been described in some detail (28-30).

In its 1978 report (29), the Radioactivity Subcommittee presented a table of dose conversion factors which conformed to the ICRP's new recommendations. The Subcommittee noted, however, that these factors would change after the ICRP published its refined dose calculations. These refined calculations were subsequently published in ICRP 30 and its Supplements (31). Based on this and other ICRP information, the concentration to dose conversion factors have been recalculated (32) and are presented in Table 15.

These values are based on "whole body" or TED_{50}-type doses. The TED_{50} given in the Agreement objective is what the ICRP calls an "effective dose equivalent" and implies the use of some value or "weight", which is a function of the risk associated with each organ dose, and then summing the risks. ICRP uses

$$\sum_T w_T H_T = \text{Effective dose equivalent}$$

where w_T is a weighting factor representing the proportion of the stochastic risk resulting from tissue (T) to the total risk, when the whole body is irradiated uniformly, and H_T is the annual dose equivalent in tissue T. The values of w_T recommended by the ICRP are given in ICRP 26, paragraph 105 (28).

An explanation as to how the values in Table 15 were derived is presented below (32).

The basic value used for all derivations is the annual limit of intake (ALI) given in ICRP 30. The ALI is that amount of radioactivity which, ingested or inhaled, gives an effective dose of 5 rem after 50 years, which is the limit based on stochastic effects. ICRP has an "effective dose equivalent" ALI. This is a risk-weighted "whole body" dose, which is equivalent to the TED_{50} referred to in the Agreement objective (see ICRP 26, paragraph 104) (28), or a "non-stochastic" limit (50 rem) for any single organ. In each case, the 1 mrem/a number given in Table 15 is based on the stochastic "whole body" effective dose equivalent value which is given in ICRP 30 (sometimes in parentheses).

The changes in Table 15 from the values presented by the Radioactivity Subcommittee in 1978 are primarily due to three factors:

1. In the 1978 table, for each radionuclide, only one "tissue at risk" was considered. However, many organs or tissues must be considered for each radionuclide. Rather than list all organs and weighted organ doses for each radionuclide, individual organs have been dropped from the table.

2. The previous table was based on estimates of what the ICRP calculations would look like. The new table is directly from ICRP 30.

3. Table 15 is now entirely based on the "weighted whole body" or effective dose concept of ICRP 30, with no organ doses given (some of these may be found in the Supplements to ICRP 30).

To illustrate the calculations performed, following is an example for ^{129}I.

TABLE 15

DOSE CONVERSION FACTORS AND SPECIFIC OBJECTIVE CONCENTRATIONS[a,b,c]

NUCLIDE	ANNUAL LIMIT OF INTAKE (Bq)	DOSE CONVERSION FACTOR ($\frac{mrem}{pCi}$)	ANNUAL INTAKE FOR 1 mrem/a (pCi)	EFFECTIVE DOSE EQUIVALENT ($\frac{mrem}{a}$ / $\frac{pCi}{L}$)	CONCENTRATION FOR 1 mrem/a (pCi/L)
^{3}H	2.9×10^{9}	6.4×10^{-8}	1.6×10^{7}	5.1×10^{-5}	20,000
^{90}Sr	1.4×10^{6}	1.3×10^{-4}	7.6×10^{3}	1.1×10^{-1}	9.4
^{226}Ra	1.7×10^{5}	1.1×10^{-3}	9.2×10^{2}	8.8×10^{-1}	1.1
^{134}Cs	2.5×10^{6}	7.4×10^{-5}	1.4×10^{4}	6.0×10^{-2}	17
^{137}Cs	3.7×10^{6}	5.0×10^{-5}	2.0×10^{4}	4.0×10^{-2}	25
^{129}I	6.7×10^{5}	2.8×10^{-4}	3.6×10^{3}	2.2×10^{-1}	4.5
^{131}I	3.5×10^{6}	5.3×10^{-5}	1.9×10^{4}	4.3×10^{-2}	24
^{60}Co	7.2×10^{6}	2.6×10^{-5}	3.9×10^{4}	2.1×10^{-2}	48
^{58}Co	5.3×10^{7}	3.5×10^{-6}	2.9×10^{5}	2.8×10^{-3}	360
^{65}Zn	1.3×10^{7}	1.4×10^{-5}	7.0×10^{4}	1.1×10^{-2}	87
^{95}Zr	5.4×10^{7}	3.4×10^{-6}	2.9×10^{5}	2.8×10^{-3}	360
^{106}Ru	8.7×10^{6}	2.1×10^{-5}	4.7×10^{4}	1.7×10^{-2}	59
^{125}Sb	7.6×10^{7}	2.4×10^{-6}	4.1×10^{5}	2.0×10^{-3}	510
^{144}Ce	9.4×10^{6}	2.0×10^{-5}	5.1×10^{4}	1.6×10^{-2}	63
^{54}Mn	6.9×10^{7}	2.7×10^{-6}	3.7×10^{5}	2.2×10^{-3}	460

a. Revised to conform to ICRP 26 and ICRP 30 (References 28 and 31, respectively).

b. Numbers in columns 2-5 have been rounded to two digits. Numbers in the last column have also been rounded to two digits, but were calculated, using unrounded numbers from the previous columns.

c. Information from Reference (32).

From ICRP, the ALI for ^{129}I = 6.7 x 10^5 Bq; it is this value which yields the 5 rem "whole body" dose. The real ALI is 2 x 10^5 Bq, which gives 50 "unweighted" rem to the thyroid. Since the Agreement has no "non-stochastic" limit for each organ, this latter value is ignored.

From page 202 of the Supplement to Part 1 of ICRP 30, the "unweighted" dose conversion factor is 2.5 x 10^{-6} Sv/Bq. The (ALI) of 6.7 x 10^5 Bq gives

$$(6.7 \times 10^5 \text{ Bq})\ (2.5 \times 10^{-6} \text{ Sv/Bq}) = 1.675 \text{ Sv} = 167.5 \text{ rem}$$

The "weight" of the thyroid is 0.03, and the "weighted" dose is

$$(1.675 \text{ Sv})\ (0.03) = 0.0503 \text{ Sv}$$

or, roughly, the 5 rem "stochastic" limit.

If one assumes that the 6.7 x 10^5Bq (ALI) gives a 5 rem limit, this can be scaled to give the millirem/picocurie dose conversion factor:

$$\frac{(6.7 \times 10^5 \text{Bq})\ (27 \text{ pCi/Bq})}{5 \times 10^3 \text{ mrem}} = \frac{1 \text{ pCi}}{x \text{ mrem}}$$

$$x = 2.76 \times 10^{-4} \text{ mrem/pCi}$$

The annual intake for 1 mrem/a is the inverse of x:

$$x^{-1} = 3.62 \times 10^3 \text{ pCi/1 mrem}$$

The Agreement objective assumes a daily ingestion of 2.2 litres of water, or 803 litres per year. Since

$$\left(\frac{1 \text{ pCi}}{\text{L}}\right)\left(\frac{803\text{L}}{\text{a}}\right) = 803 \text{ pCi/a}$$

then

$$\left(\frac{803 \text{ pCi}}{\text{a}}\right)\left(\frac{x \text{ mrem}}{\text{pCi}}\right) = 0.222 \frac{\text{mrem/a}}{\text{pCi/L}}$$

The inverse of this is the last column in Table 15, that is, the concentration which yields the Agreement objective of 1 mrem/a:

$$\frac{1}{\frac{0.222 \text{ mrem/a}}{\text{pCi/L}}} = 4.5 \frac{\text{pCi/L}}{\text{mrem/a}}$$

JURISDICTIONAL LIMITATIONS

Both Canada and the United States have limitations for the concentration of radionuclides in drinking water. These limitations are presented in Table 16, along with the concentrations which would result in a dose of 1 mrem - the Agreement objective.

TABLE 16

LIMITATIONS ON RADIONUCLIDES IN WATER

RADIONUCLIDE	CONCENTRATION IN pCi/L							
	U.S. EPA NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS (1977-PRESENT)[h]	ONTARIO MOE PROVINCIAL WATER QUALITY OBJECTIVES (1964-1982)[d]	CANADA DNHW - RECOMMENDED LIMITS FOR RADIONUCLIDES IN DRINKING WATER (1968-1977)[e]			CANADA DNHW (1978-PRESENT)[f] ONTARIO MOE (1983-PRESENT)[g]		CONCENTRATION EQUIVALENT TO AGREEMENT OBJECTIVE OF 1 mrem/a
			OBJECTIVE	ACCEPTABLE	MPL[i]	TARGET[b]	MAC[b,j]	
^{3}H	2×10^{4}	-	3×10^{6}	1×10^{7}	3×10^{7}	1.08×10^{5}	1.08×10^{6}	2×10^{4}
^{90}Sr	8[c]	10	400	1,300	4,000	27	270	9.4
^{131}I	3	-	2,000	6,000	20,000	27	270	24
^{137}Cs	200	-	20,000	60,000	200,000	140	1,400	25
^{226}Ra	-	3	10	30	100	2.7	27	1.1
$^{226}Ra + {}^{228}Ra$	5	-	-	-	-	-	-	-
Gross α	15[a]	-	-	-	-	-	2.7[k]	-
Gross ß	50	-	-	-	-	-	27[k]	-
U (µg/L)	-	-	-	-	-	1	20	-

a. Excluding radon and uranium.
b. Objectives are officially presented as Bq/L, but have been converted to pCi/L using the conversion factor: 1 Bq = 27 pCi.
c. 4 mrem, from 40 CFR 141.
d. From Reference (34).
e. From Reference (67).
f. From Reference (26).
g. From Reference (33).
h. From Reference (35).
i. MPL = maximum permissible limit.
j. MAC = maximum acceptable concentration.
k. Screening limit.

The U.S. EPA's National Interim Primary Drinking Water Regulations (35) for radioactivity became effective June 24, 1977 and became, in essence, the standards by which all drinking water supplies in the United States are judged. These values are based on ICRP 2.

The guidelines - both past and present - published by the Canada Department of National Health and Welfare (DNHW) have been based on the recommendations of the ICRP for the occupational intake of radionuclides, with "safety factors" incorporated to render them applicable to the public. As the body of available scientific data has increased, a number of changes have taken place in the ICRP recommendations. These changes have served as the basis for changes in the guidelines adopted by both DNHW and by the Province of Ontario. The major changes, as they pertain to ^{226}Ra and ^{90}Sr, are summarized below (74).

In 1959, the maximum permissible concentration (MPC) for ^{226}Ra in water was 100 pCi/L and, for ^{90}Sr 1,000 pCi/L, for continuous occupational exposure (24 hours per day, 365 days per year) (70). The ICRP acknowledged at that time, however, that the calculations on which the MPC's were based were a "drastic oversimplification" for many radionuclides, and especially for the bone-seeking ones. The assumption employed was that a radionuclide which had accumulated in an organ would be eliminated at a constant rate (i.e. an exponential model).

For bone-seeking radionuclides, data supported the view that the fraction eliminated varied inversely with time (i.e. a power function model). Using the power function model, MPC's of 1,000 and 6,000 pCi/L were calculated, respectively, for ^{226}Ra and ^{90}Sr. Nonetheless, the ICRP recommended the lower values, calculated from the exponential model, "in large part ... by the desire to give a unified and economical presentation of the material."

By 1962, extensive data had become available on the metabolism of strontium and calcium. The new data indicated lower strontium-to-calcium ratios in new bone than had previously been assumed, and a large data base had been assembled on the concentrations of strontium and calcium in bone. Consequently, the MPC for ^{90}Sr in water was revised upwards to 4,000 pCi/L (71). This revised MPC, based on the new information, was not very different from that resulting from the previous calculation using the power function model.

In 1972, the ICRP published a detailed analysis of the metabolism of alkaline earth elements (72). The analysis clearly demonstrated that a power function model, with modifications to account for very short- and for very long-term observations, gave a much better fit to the observed data and more closely described the processes of bone physiology than a simple exponential function. This model was subsequently used in the ICRP's most recent calculations.

Although α-emitting radionuclides, such as ^{226}Ra and ^{90}Sr, are incorporated into bone, the ICRP has recognized, since 1959, that bone is one of the least sensitive tissues to radiation damage. Until 1976, the occupational dose limit for bone was 30 rem per year. In 1976, the concept of

weighted risk implied that a dose of 170 rem to bone would result in the same risk of cancer as 5 rem to the whole body (28). To protect against non-stochastic effects, the occupational annual limit of intake (ALI) was based on a dose commitment of 50 rem to bone from a one-year intake.

The result of the above-described changes is that the concentration corresponding to the occupational dose limit for the continuous ingestion of ^{226}Ra has changed from 100 pCi/L in 1959 to 2,700 pCi/L in 1979 and, for ^{90}Sr, from 1,000 to 27,000 pCi/L, in each case, a factor of 27.

Also, during this time, the ICRP has become less precise in its recommendations for the protection of the general population. In 1959 and again in 1962, dose limits for individual members of the public, at the boundary of a facility, were 1/10 of the occupational recommendations. The ICRP presented detailed instructions to protect the population at large from genetic and somatic damage, with recommended factors of 1/100 and 1/30, respectively. In 1965, the ICRP retained the 1/10 factor for individuals, but withdrew the safety factors for populations, on the grounds that they would vary substantially, depending on circumstances (73).

A limit of 3 pCi/L for the consumption of ^{226}Ra in water was originally established by DNHW (74). This value was equivalent to (if not based on) 1/30 of the limit established in 1959 for the consumption of ^{226}Ra over a 168-hour (7-day) period (MPC_w); the 1/30 was the recommended safety factor for protection of the population at large from somatic damage. This safety factor was withdrawn in 1965.

In 1968, DNHW published (67) a limit (objective concentration) of 1/10 of the MPC_w "as the long-term quality goal to be reached," and a limit (acceptable concentration) of 1/3 of the MPC_w, which "should not be exceeded whenever more suitable supplies are, or can be made, available ... within ... the community." The MPC_w itself served as the maximum permissible limit (MPL) which, "if exceeded, shall be sufficient grounds for the rejection of the water supplies unless effective remedial treatment is applied."

In 1978, DNHW published (26) revised guidelines for radiological characteristics; these guidelines introduced safety factors of 1/1000 and 1/100. The resulting concentration limits correspond to the objective (target) concentration and the maximum acceptable concentration (MAC), respectively. The target concentration and the MAC are similar in philosophy to the previous objective concentration and the MPL.

In 1982, the Ontario Ministry of the Environment revised (33) the provincial water quality objectives for radionuclides to correspond to the changes promulgated by the ICRP and DNHW.

6. Aquatic Surveillance and Monitoring - 1981 and 1982

INTRODUCTION

The Great Lakes International Surveillance Plan (36) calls for surveillance and monitoring of radioactivity in the Great Lakes basin. The Plan calls for programs which measure specific radionuclides in the ambient waters, source control areas, potable water supplies, fish, and sediment. The jurisdictions conduct the programs which provide the data. The programs not only measure the level of radioactivity present in the Great Lakes ecosystem, as a result of inputs from the various sources, but the programs, collectively, also help to meet three specific requirements of Annex 11 of the 1978 Agreement:

1. Assessment of the degree to which jurisdictional control requirements are being met.
2. Achievement of the specific Agreement objective, given in Annex 1, which was established to protect human health.
3. Evaluation of water quality trends.

Radiological surveillance and monitoring data collected by the jurisdictions during 1981 and 1982 are presented in Tables 25 - 46.

The monitoring data collected in the vicinity of nuclear facilities and operations in the basin, in conjunction with the release data presented in Chapter 3, are used to assess the degree to which jurisdictional control requirements are being met, as well as changes over time and, consequently, the effectiveness of particular remedial measures. The Ontario Ministry of the Environment program on the Serpent River, which dates from 1966, in particular demonstrates the dramatic change in water quality and the efficacy of remedial measures implemented in that river basin.

The data collected in the open waters of the lakes, at public water intakes, and at certain source control areas are used to determine compliance with the Agreement objective, as well as with jurisdictional limitations.

The data collected in the open water by the National Water Research Institute and at selected public water intakes by the Department of National Health and Welfare are used to evaluate radiological trends over time. The open water samples are collected at several locations in each lake, near the surface and near the bottom and, in effect, present an "integrated" measure of radioactivity in the lakes. The program dates from 1973.

The National Health and Welfare public water intake program dates from 1963. The sites were selected because of their proximity to various nuclear facilities and operations. Both of the above-mentioned programs present the advantage of a long-term data base.

In addition to the routine monitoring of radioactivity levels at selected public water intakes and in the vicinity of nuclear facilities, additional samples are collected in the event of an unplanned release. The data from these additional samples help to establish whether any measurable increase in concentration has occurred and whether drinking water limitations are exceeded.

DOSE TO MAN

The Agreement objective is in terms of a dose to man. The dose assumes ingestion of 2.2 litres of water per day for one year. The estimated doses resulting from the ingestion of water from each of the Great Lakes for 1981 and 1982 are presented in Table 17. These values were determined, using the mean open lake concentration data presented in Table 27, and using the conversion factors given in Table 15.

The annual doses for 1981 are 0.05, 0.07, 0.09, 0.08, and 0.09 mrem for Lakes Superior, Michigan, Huron, Erie, and Ontario, respectively. The annual doses for 1982 are 0.05, 0.09, 0.08, and 0.10 mrem for Lakes Superior, Huron, Erie, and Ontario, respectively; there are no open lake data with which to calculate an annual dose from ingestion of Lake Michigan water for 1982. These values are all well less than the Agreement objective of 1 mrem. In each case, ^{90}Sr contributes 80-90% of the total dose. The major source of this radionuclide is fallout from nuclear weapons testing.

In the Serpent River area, on the North Channel of Lake Huron, ^{226}Ra also contributes significantly to the total dose. The mean concentrations of ^{226}Ra in water samples collected upstream of the mouth of the Serpent River (Table 34) convert into annual doses of 1.42 and 1.30 mrem for 1981 and 1982, respectively. The dose resulting from the presence of ^{226}Ra is in addition to that expected from other radionuclides present.

According to the Agreement objective, a dose between 1 and 5 mrem at the periphery of a source control area calls for investigation of the source and corrective action, if releases are not as low as reasonably achievable. The source control area in this case has been defined as the mouth of the Serpent River, and the critical value is the concentration of ^{226}Ra measured at the periphery of the source control area. However, the mean ^{226}Ra concentrations, referred to above, are measured 8.4 km upstream from the mouth of the river. Measurements made on selected dates at stations located in Serpent Harbour, i.e. at the periphery of the source control area (Tables 35 and 36) indicate that the concentration of ^{226}Ra near the mouth of the river occasionally exceeds 1.1 pCi/L, which is the concentration equivalent to an annual dose of 1 mrem. The data also indicate that the concentration decreases to values near or less than the analytical detection limit, as one proceeds out into the harbour. The frequency of sample collection and the nature of the data produced are such that an annual dose, resulting from the presence of ^{226}Ra, cannot be calculated at the periphery of the source control area.

Presented below in the Lake Huron section, is a comparison of ^{226}Ra concentrations with jurisdictional limitations, as is a discussion of changes in concentration over time.

TABLE 17

EXPECTED DOSES FROM INGESTION OF GREAT LAKES WATER
(Doses in mrem)

RADIONUCLIDE	YEAR	LAKE				
		SUPERIOR	MICHIGAN	HURON	ERIE	ONTARIO
^{3}H	1981	0.0084	0.0090	0.0132	0.0115	0.0183
^{90}Sr		0.0426	0.0564	0.0723	0.0638	0.0734
^{137}Cs		0.0019	0.0016	0.0014	0.0008	0.0010
^{125}Sb		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Total		0.053	0.067	0.087	0.076	0.093
^{226}Ra		-	-	1.42[a]	-	-
^{3}H	1982	0.0073	-	0.0124	0.0164	0.0118
^{90}Sr		0.0436	-	0.0777	0.0670	0.0840
^{137}Cs		0.0018	-	0.0012	0.0006	0.0012
^{125}Sb		<0.0001	-	<0.0001	<0.0001	<0.0001
Total		0.053	-	0.091	0.084	0.097
^{226}Ra		-	-	1.30[a]	-	-

a. Serpent River

RADIONUCLIDES IN WATER

LAKE SUPERIOR

Tables 25 and 26 present radiological monitoring data for samples collected from the open waters of Lake Superior during 1981 and 1982, respectively. These data indicate that the concentrations of radionuclides remain low and, as discussed above, the total annual dose to man resulting from the ingestion of water from Lake Superior was 0.05 mrem in both 1981 and 1982.

The mean concentration of uranium in the open waters of Lake Superior was 0.16 µg/L in 1981 and 0.08 µg/L in 1982 (Table 27). These are below the target concentration of 1 µg/L, established by National Health and Welfare, and more than one hundred times less than that Department's maximum acceptable concentration of 20 µg/L for uranium in drinking water (26).

Table 18 summarizes the average open lake concentrations of ^{90}Sr, ^{137}Cs, and ^{125}Sb observed in Lake Superior from 1973 through 1982. The ^{90}Sr data indicate no apparent trend with time. The average annual ^{137}Cs concentrations for the period 1976-1982 are lower than the averages calculated for 1973 and 1974. The average annual ^{125}Sb concentrations fluctuate from year to year; however, the reported values are all near the analytical detection limit, so discernment of trends is not possible.

LAKE MICHIGAN

Table 25 presents radiological monitoring data for samples collected from the open waters of Lake Michigan during 1981. Tables 28 - 31 summarize data for samples collected during this same time period in the vicinity of nuclear generating stations and at selected public water intakes.

The open lake data indicate that the total dose to man from the ingestion of water from Lake Michigan was 0.07 mrem for 1981. No open lake samples were collected during 1982, and the other available data (Tables 28-31) are too sparse to allow an estimate of dose for that year.

The mean concentration of uranium in the open waters of Lake Michigan in 1981 was 0.38 µg/L (Table 27), which is below the target concentration of 1 µg/L, established by National Health and Welfare (26).

Table 19 summarizes average radionuclide concentrations for Lake Michigan from 1973 through 1981. These data are from several sources and locations; therefore, strict comparison between values for different years is not advisable. The data from the National Water Research Institute are for samples collected at open-lake stations located throughout the lake and are indicators of whole-lake conditions. The other data are from inshore locations in the vicinity of nuclear generating stations and from drinking water intakes.

TABLE 18

LAKE SUPERIOR - AVERAGE OPEN-WATER CONCENTRATIONS[a]

YEAR	CONCENTRATION IN pCi/L		
	^{90}Sr	^{137}Cs	^{125}Sb
1973	0.53	0.087	0.044
1974	-	0.076	0.038
1976	-	0.051	<0.010-0.038
1978	0.30	0.053	0.028
1979	0.50	0.045	0.047
1980	0.30	0.055	0.019
1981	0.40	0.047	0.02
1982	0.41	0.045	<0.012

a. All data from National Water Research Institute, Burlington, Ontario. See References (3, 38, and 75).

TABLE 19

LAKE MICHIGAN - AVERAGE ANNUAL CONCENTRATIONS

YEAR	CONCENTRATION IN pCi/L			
	^{90}Sr	^{137}Cs	^{125}Sb	^{3}H
1973	0.83[a]	0.046[a]	-	-
1974	-	-	-	300
1976	-	-	-	350
1977	1.1	-	-	330
1978	1.3	-	-	400
1979	0.83[a]	0.035[a]	0.052[a]	400
1980	0.63[a]	0.044[a]	0.021[a]	400
1981	0.53[a]	0.039[a]	0.02[a]	180[a]

a. Averages based on open-water samples analyzed by National Water Research Institute, Burlington, Ontario. See References (3) and (38).

These data indicate that the average concentration of ^{90}Sr in Lake Michigan continues to decrease and that the concentration of ^{137}Cs remains essentially unchanged. The observed concentrations of ^{125}Sb are near the analytical detection limits, so discernment of trends is not possible.

The reported concentrations of ^{3}H are also near the analytical detection limits. The mean open water concentration for 1981 was 180 pCi/L (Table 27), and the mean concentration in samples collected in the vicinity of nuclear generating stations was approximately 300 pCi/L for both 1981 and 1982 (from Tables 30 and 31). Collectively, when compared with average values from prior years, these data indicate little, if any, change with time.

LAKE HURON

Tables 25 and 26 present radiological monitoring data for samples collected from the open waters of Lake Huron, Georgian Bay, and the North Channel during 1981 and 1982, respectively. Tables 28 and 29 summarize data for samples collected during this same time period at public water intakes. Tables 34 - 36 summarize data for samples collected near the mouth of the Serpent River and in Serpent Harbour, and Tables 37 and 38 summarize data for samples collected in the vicinity of the Bruce Nuclear Power Development. Also available are ^{3}H data for weekly composite samples collected from the cooling water discharge at both the Douglas Point and the Bruce "A" nuclear generating stations. These data are not presented here, since the samples were collected within the source control areas for these facilities.

The open lake data indicate that the total dose to man from ingestion of water from Lake Huron was 0.09 mrem in both 1981 and 1982.

The average concentration of ^{90}Sr reported in raw water samples collected at the Kincardine and Port Elgin public water intakes in 1981 was 0.39 pCi/L, which is less than the mean value of 0.68 pCi/L reported for the open waters (Table 27) and a mean of 0.80 pCi/L reported for water samples collected in the vicinity of the Bruce Nuclear Power Development (Table 37). For 1982, the average at the two water intakes was 0.31 pCi/L, which is again less than the mean value of 0.73 pCi/L reported for the open waters (Table 27) and the mean of 0.68 pCi/L reported for water samples collected in the vicinity of the Bruce development (Table 38).

Table 20 summarizes average annual concentrations of ^{90}Sr measured at the Kincardine and the Port Elgin public water intakes since 1963, and in the open waters of Lake Huron since 1973.

The water intake data indicate an apparent maximum concentration of 1.01 pCi/L for ^{90}Sr in 1965 and essentially no change for the period 1967-1978. However, average values reported for 1979 through 1982 indicate a downward trend. Open water data for the period 1973-1982, however, indicate no particular trend; this is supported by data from the vicinity of the Bruce development.

TABLE 20

^{90}Sr, ^{137}Cs, AND ^{125}Sb IN LAKE HURON WATER
1963 - 1982[a,b]

YEAR	CONCENTRATION IN pCi/L								
	KINCARDINE		PORT ELGIN		AVERAGE		OPEN WATER		
	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{125}Sb
1963	0.60	0.37	0.75	0.40	0.68	0.38	-	-	-
1964	0.80	0.30	0.76	0.28	0.78	0.29	-	-	-
1965	0.96	0.19	1.06	0.19	1.01	0.19	-	-	-
1966	0.85	0.18	0.94	0.09	0.90	0.14	-	-	-
1967	0.76	0.11	0.84	0.06	0.80	0.08	-	-	-
1968	0.70	0.08	c	c	-	-	-	-	-
1969	0.66	0.06	c	c	-	-	-	-	-
1970	0.66	0.06	c	c	-	-	-	-	-
1971	0.75	<0.10	0.84	<0.10	0.80	<0.10	-	-	-
1972	0.71	<0.10	0.74	<0.10	0.72	<0.10	-	-	-
1973	0.70	<0.10	0.80	<0.10	0.75	<0.10	0.86	0.04	0.08
1974	0.75	0.07	0.79	0.04	0.77	0.05	-	0.05	0.07
1975	0.72	0.04	0.76	0.03	0.74	0.03	-	0.04	0.06
1976	0.71	0.06	0.74	0.09	0.72	0.07	-	0.02	0.04
1977	0.64	0.03	0.68	0.02	0.66	0.02	0.84	0.04	0.06
1978	0.67	0.03	0.69	0.08	0.68	0.05	0.61	0.03	0.03
1979	0.51	0.05	0.51	0.05	0.51	0.05	0.78	0.03	0.05
1980	0.54	0.03	0.54	<0.03	0.54	<0.03	0.70	0.05	0.03
1981	0.32	0.05	0.46	0.03	0.39	0.04	0.68	0.03	0.03
1982	0.24	0.03	0.38	0.08	0.31	0.05	0.73	0.03	<0.014

a. Information from References (3, 30, 38, 39, and 75).
b. Raw water.
c. Not sampled.

The average concentration of ^{137}Cs reported in raw water at the Kincardine and the Port Elgin public water intakes in 1981 was 0.041 pCi/L, which is comparable to the mean value of 0.034 pCi/L reported for the open waters. For 1982, the average at the two water intakes was 0.054 pCi/L and, in the open waters, 0.031 pCi/L.

Table 20 summarizes average annual concentrations for ^{137}Cs for the past 20 years. The average ^{137}Cs concentration reported for the Port Elgin and Kincardine public water intakes in 1963 was 0.38 pCi/L, almost ten times the average reported since 1974. The data available for 1981 and 1982 indicate that the ^{137}Cs concentration continues to hold steady.

The open water data indicate that the average ^{125}Sb concentration for 1981 is similar to averages reported for 1976-1980, and lower than averages reported in 1973-1974. The average for 1982 appears to be lower than that for 1981.

The average concentration of ^{3}H reported in the open waters of Lake Huron was 264 pCi/L in 1981 and 247 pCi/L in 1982. The average values reported in the vicinity of the Bruce Nuclear Power Development were approximately 1000 pCi/L for both 1981 and 1982 (Tables 37 and 38). This elevation above the ambient is expected, since ^{3}H is the major radionuclide released from a CANDU reactor. The maximum concentration reported near the periphery of the Bruce source control area during 1981 and 1982 was 6490 pCi/L. If this concentration had persisted for a full year, the dose to man would have been 0.32 mrem. The average ^{3}H concentration observed would have resulted in a dose of about 0.05 mrem, compared to a dose from ^{3}H in the open water of 0.01 mrem. All these values are below the Agreement objective of 1 mrem.

The concentrations of ^{226}Ra reported for the Serpent River and the Serpent Harbour area (Tables 34-36) are all less than the maximum acceptable concentration of 27 pCi/L, established by both National Health and Welfare and the Ontario Ministry of the Environment (see Table 16). The maximum reported concentration was 3 pCi/L, which is slightly in excess of the target concentration of 2.7 pCi/L established by these two agencies.

Table 8 summarizes the releases of total and dissolved ^{226}Ra from uranium mining facilities in the Serpent River basin for 1979, 1980, and 1981. The quantity of total ^{226}Ra released during 1981 was 817 mCi, and the quantity of dissolved ^{226}Ra released was 145 mCi. This compares with a loading of 807 mCi from the Serpent River in 1981 (see Table 34). The total load was calculated by multiplying the average flow by the weighted average concentration.

Considering just the dissolved ^{226}Ra, the difference between the release from mine and mill sites and the loading reported from the river can be attributed to natural inputs plus leaching from uncontrolled and/or abandoned sites. In addition, although the nondissolved component of the total quantity released from mines and mills would not be expected to remain in the water column for long, its presence does constitute an additional potential source to the water column.

Table 21 shows that the average annual concentration of ^{226}Ra in the Serpent River has decreased dramatically since 1966. The decrease has been attributed to decreased mining activity, reuse of process waters, the treatment of process waters with barium chloride prior to release from active mine sites, and the treatment of runoff from abandoned or closed mines.

The mean concentration of uranium in the open waters of Lake Huron, Georgian Bay, and the North Channel was 0.26 µg/L in 1981 and 0.39 µg/L in 1982 (Table 27); these values are less than the target concentration of 1 µg/L established by National Health and Welfare (26). The concentrations of ^{238}U observed near the mouth of the Serpent River during 1981 and 1982 are all less than 10 µg/L (Table 34). The maximum acceptable concentration for uranium in drinking water is 20 µg/L, also established by National Health and Welfare (26).

LAKE ERIE

Tables 25 and 26 present radiological monitoring data for samples collected from the open waters of Lake Erie during 1981 and 1982, respectively. Tables 28, 29, and 32 summarize data for samples collected during this same time period in the vicinity of nuclear generating stations and at drinking water intakes.

The open lake data indicate that the total dose to man from ingestion of water from Lake Erie was 0.08 mrem for both 1981 and 1982. Available nearshore and water intake data for 1981 corroborate the open lake concentration values.

Table 22 summarizes average radionuclide concentrations for Lake Erie from 1973 through 1982. The mean ^{90}Sr concentration appears to fluctuate from year to year, but no trend is apparent. The ^{137}Cs, ^{125}Sb, and ^{3}H data indicate no trend with time. The values reported for the last two radionuclides are close to the analytical detection limits.

The mean concentration of uranium in the open waters of Lake Erie was 0.43 µg/L in 1981 and 0.59 µg/L in 1982 (Table 27). These are less than the target concentration of 1 µg/L established by National Health and Welfare (26).

Discharges and runoff from the Western New York Nuclear Service Center enter Buttermilk Creek which, in turn, discharges into Cattaraugus Creek, which empties into Lake Erie. Although the site is not in operation as a reprocessing facility, it does continue to function as a waste storage and burial facility. Small amounts of radioactive waste are discharged to the environment. Water samples collected below the discharge from the Center contain measurable levels of radioactivity attributable to the facility. Potential sources of radioactivity include decontamination of buildings or equipment, operation of the spent fuel storage pool, leakage from pipes or tanks, and discharges from the burial site (37).

TABLE 21

AVERAGE ANNUAL CONCENTRATION OF ^{226}Ra IN THE SERPENT RIVER, 1966-1982[a,b]

DATE	CONCENTRATION, pCi/L
1966	11.7
1967	8.8
1968	8.8
1969	7.3
1970	8.7
1971	6.5
1972	5.7
1973	6.1
1974	5.5
1975	5.4
1976	5.3
1977	4.8
1978	2.43
1979	1.93
1980	1.58
1981	1.56
1982	1.43

a. Measured at Hwy. 17 bridge, 8.4 km upstream from the harbour - Station No. 140019-1.
b. Information from References (3, 27, 30, 47, 49, and 50).

TABLE 22

LAKE ERIE - AVERAGE ANNUAL CONCENTRATIONS

YEAR	CONCENTRATION IN pCi/L			
	^{90}Sr	^{137}Cs	^{125}Sb	^{3}H
1973	1.06[a]	0.02[a]	0.09[a]	-
1974	0.99	<0.07	-	340
1975	1.02	-	-	330
1976	-	-	-	360
1977	0.81[a]	0.02[a]	0.04[a]	320
1978	0.57[a]	0.02[a]	0.05[a]	330
1979	0.83[a]	0.02[a]	0.04[a]	-
1980	0.39[a]	0.02[a]	0.03[a]	-
1981	0.60[a]	0.02[a]	0.03[a]	230[a]
1982	0.63[a]	0.01[a]	0.02[a]	328[a]

a. Averages based on open-water samples analyzed by National Water Research Institute, Burlington, Ontario. See References (3, 38, and 75).

Samples taken on the site of the reprocessing plant during 1981 continue to indicate at least two sources of shallow groundwater contamination. One source is a spring which, it is believed, is recharged in shallow sand and gravel at higher ground near the spring (37).

In order to prevent further seepage from the trench coverings at the low-level burial site, trench water is pumped out to on-site holding lagoons. The water is treated for removal of cesium and strontium, collected in two small lagoons, and eventually discharged to Buttermilk Creek through a calibrated weir (37). Radioactivity levels in watercourses below the main plant and below the low-level burial site, continue to show some ^{3}H activity resulting from these operations.

The average annual concentrations of gross α, gross β, and ^{90}Sr, measured during 1981 and 1982 at Springville Dam on Cattaraugus Creek, are comparable to averages reported in previous years (Table 23). The average ^{3}H level for 1981 was elevated over levels reported for the past several years; nonetheless, the average annual concentration was only 3.2% of the U.S. Nuclear Regulatory Commission's technical specifications for the creek.

LAKE ONTARIO

Tables 25 and 26 present radiological monitoring data for samples collected from the open waters of Lake Ontario during 1981 and 1982, respectively. Tables 28 and 29 summarize data for samples collected during this same time period at public water intakes. Tables 39 and 40 summarize data for samples collected in the vicinity of nuclear generating stations, and Tables 41 through 44 present data for samples collected from Port Hope Harbour and in the vicinity of the Welcome and Port Granby dumps. Also available are ^{3}H data for weekly composite samples collected from the cooling water discharge at the Pickering nuclear generating station. These data are not presented in this report, since the samples were collected within the source control area.

The open lake data indicate that the total doses to man from ingestion of water from Lake Ontario were 0.09 and 0.10 mrem for 1981 and 1982, respectively.

The average concentration of ^{90}Sr reported in raw water samples collected at the Toronto and the Ajax public water intakes in 1981 was 0.47 pCi/L. This is less than the average reported open water concentration of 0.69 pCi/L and the average of about 0.83 pCi/L reported for samples collected in the vicinity of the Pickering nuclear generating station (Table 39). For 1982, the average at the two water intakes was 0.41 pCi/L, in the open waters 0.79 pCi/L, and at the Pickering facility 0.77 pCi/L (Table 40).

The average ^{137}Cs levels reported for the open waters of Lake Ontario in 1981 and for the Toronto and Ajax public water intakes were the same, 0.027 pCi/L. For 1982, the average at the two water intakes was 0.054 pCi/L and, in the open waters, 0.029 pCi/L.

TABLE 23

CATTARAUGUS CREEK WATER AT SPRINGVILLE DAM

1968 - 1982[a,b]

YEAR	AVERAGE ANNUAL CONCENTRATION IN pCi/L			
	GROSS α	GROSS β	^{90}Sr	^{3}H
1968	-	123	25	22,000
1969	-	214	47	17,600
1970	-	222	69	19,600
1971	c	208	37	31,000
1972	c	169	9	2,200
1973	c	19	4	<500
1974	<4	15	<3	<800
1975	<4	11	<3	6,200
1976	<5	10	<2	8,400
1977	<5	7	1	1,800
1978	<4	7	1	2,770
1979	<3	5	1	350
1980	<5	5	1	220
1981	<8.4	<9.5	<1.6	<9,600
1982	<6	<7.5	<1	<362
Maximum Permissible Concentrations:[h]				
NRC Technical Specifications for Nuclear Fuel Services[d]	-	-	30	300,000
EPA Drinking Water Standard	15[g]	50[f]	8[e]	20,000[e]

a. Information from References (3, 30, 37, and 76).
b. Measured at Springville Dam (Site 1459-042).
c. Not detected.
d. 10 percent of 10 CFR 20.
e. 4 mrem, from 40 CFR 141.
f. If gross β >50 pCi/L, then analysis for specific radionuclides must be performed.
g. Combined ^{226}Ra and ^{228}Ra = 5 pCi/L maximum.
h. If sole source of radioactivity.

^{3}H levels measured at the Pickering "A" nuclear generating station source control area (Tables 39 and 40) show frequent elevations above the ambient levels for the dates sampled in both 1981 and 1982. The maximum reported concentration was 4,320 pCi/L; if this concentration had persisted for a full year, the dose to man would have been 0.22 mrem. The average concentration for the Pickering source control area was about 500 pCi/L in 1981 and about 900 pCi/L in 1982, compared with an average open water concentration of 366 pCi/L in 1981 and of 235 pCi/L in 1982.

^{3}H data collected at public water intakes (Tables 28 and 29) during 1981 and 1982 corroborate the open water findings.

Table 24 summarizes the average annual concentrations of ^{90}Sr and ^{137}Cs measured at the Pickering, Ajax, and Toronto public water intakes since 1971, and of ^{90}Sr, ^{137}Cs, and ^{125}Sb, measured in the open waters of Lake Ontario since 1973.

The water intake data indicate that the average annual concentration of ^{90}Sr is lower for the period 1979-1982 than for the period 1971-1978. However, the open water data do not indicate such a trend.

The average annual ^{137}Cs concentrations for samples collected at both public water intakes and in the open water are in general agreement and indicate that levels have remained relatively unchanged since at least 1976.

The open water data indicate that the average ^{125}Sb concentrations for 1981 and 1982 are similar to averages reported for 1976-1980, and lower than the average reported for 1973. Present average concentrations are close to the analytical detection limit.

The mean concentration of uranium in the open waters of Lake Ontario was 0.50 µg/L in 1981 and 0.42 µg/L in 1982 (Table 27). These are below National Health and Welfare's target of 1 µg/L (26).

The waters of Port Hope Harbour receive waste from the Eldorado Resources Ltd. refinery. The concentration of uranium inside the harbour, for the five sampling dates in 1981, was generally above the maximum acceptable concentration of 20 µg/L set by National Health and Welfare (26); the maximum concentration reported was 650 µg/L (Table 41). Similar findings are reported for the four sampling dates in 1982, with a maximum reported concentration of 110 µg/L (Table 42). These findings are consistent with concentrations reported in prior years (3, 30).

The concentration of uranium in water outside Port Hope Harbour in 1981 and 1982 is generally less than the maximum acceptable concentration of 20 µg/L, but excursions as high as 49 and 63 µg/L were reported for 1981 and 1982, respectively (Tables 41 and 42). These findings are also consistent with concentrations reported in prior years (3, 30).

The concentration of uranium in Lake Ontario water in the vicinity of the Welcome and the Port Granby dumps for the dates sampled during 1981 and 1982 is less than the maximum acceptable concentration of 20 µg/L (Tables 43 and 44). Most concentrations were reported to be less than 3 µg/L, the detection limit of the analytical method used.

TABLE 24

^{90}Sr, ^{137}Cs, AND ^{125}Sb IN LAKE ONTARIO WATER
1971 - 1982[a]

YEAR	CONCENTRATION IN pCi/L										
	PICKERING		AJAX		TORONTO		AVERAGE		OPEN WATER		
	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{125}Sb
1971	0.80	-	0.83	-	1.04	-	0.89	-	-	-	-
1972	0.82	0.31	0.93	0.24	1.30	0.22	1.01	0.26	-	-	-
1973	0.85	0.06	0.88	0.15	0.94	0.08	0.89	0.10	1.26	0.05	0.09
1974	0.95	0.37	0.85	0.11	0.87	0.07	0.89	0.18	-	-	-
1975	0.82	0.12	0.95	0.04	0.91	0.04	0.89	0.07	-	-	-
1976	0.82	0.04	0.82	0.09	0.84	0.05	0.83	0.06	-	0.02	0.02
1977	0.91	0.05	0.96	0.08	0.95	0.04	0.94	0.06	0.93	0.02	0.04
1978	0.82	0.04	0.78	0.05	0.86	0.04	0.82	0.04	0.60	0.03	0.03
1979	0.51	<0.03	0.59	0.11	0.62	<0.03	0.57	0.06	0.88	0.03	0.03
1980	0.27	<0.03	0.54	<0.03	0.54	0.05	0.45	0.04	0.86	0.03	0.03
1981	b	b	0.41	0.03	0.54	0.03	0.48	0.03	0.69	0.03	0.02
1982	b	b	0.38	0.05	0.43	0.05	0.41	0.05	0.79	0.03	0.01

a. Information from References (3, 30, 38, 39, and 75).
b. No longer sampled.

The average concentration of uranium in treated drinking water at Port Hope was 1.5 µg/L in 1981 and 1.4 µg/L in 1982 (Tables 28 and 29). These are consistent with levels reported in previous years (3, 30).

The concentration of ^{226}Ra inside Port Hope Harbour, for the dates sampled in 1981 and 1982, was generally near or below the detection limit of 1 pCi/L (Tables 41 and 42). All concentrations reported outside the harbour were less than 1 pCi/L, as were values for all samples collected off the Welcome and Port Granby dumps (Tables 43 and 44).

Canada and Ontario guidelines have screening limits of 2.7 and 27 pCi/L, respectively, for gross α and gross β radioactivity in water (see Table 16). The concentration of dissolved gross α reported inside Port Hope Harbour, for the dates sampled in 1981 and 1982, was greater than 2.7 pCi/L (Tables 41 and 42). The maximum reported dissolved gross α concentrations for the two years were 930 and 173 pCi/L, respectively (intake and discharge locations excluded). In addition, the concentration of dissolved gross α in water outside the harbour was also frequently in excess of 2.7 pCi/L. These findings are consistent with results reported in previous years (3, 30).

The concentration of dissolved gross β reported inside Port Hope Harbour, for the dates sampled in 1981 and 1982, was occasionally greater than 27 pCi/L (Tables 41 and 42). The maximum reported dissolved gross β concentrations for the two years were 180 and 15 pCi/L, respectively (intake and discharge locations excluded). All observations of dissolved gross β outside the harbour were, however, less than 27 pCi/L. These values appear to be consistent with results reported in previous years (3, 30).

The maximum concentrations of dissolved gross α reported off the Welcome and Port Granby dumps in 1981 and 1982 were 28 and 14 pCi/L, respectively (Tables 43 and 44). The maximum concentrations of dissolved gross β reported for these two years were 7 and 24 pCi/L, respectively. These values appear to be consistent with results reported in previous years (3, 30).

FISH FROM THE GREAT LAKES

The concentrations of radionuclides in whole fish collected from the Great Lakes in 1981 and 1982 are given in Tables 45 and 46, respectively. As noted for fish collected in 1980, the concentration of ^{137}Cs is higher in fish from Lake Huron than from both Lake Erie and Lake Ontario.

The concentration of ^{137}Cs reported in samples of whole rainbow trout from the Ganaraska River, Lake Ontario may be decreasing. The observed average values (3, 29, 30, 38) from 1976 through 1981 are:

1976	64 pCi/kg
1977	53 pCi/kg
1978	60 pCi/kg
1980	72 pCi/kg
1981	37 pCi/kg

COMPARISON AMONG THE LAKES

The water samples collected from the open waters of the Great Lakes in 1981 and 1982 provide an opportunity to compare conditions among the lakes.

The concentrations of ^{137}Cs, ^{125}Sb, ^{90}Sr, and uranium in each lake did not show any large variations from station to station or between top and bottom for 1981 and for 1982 (Tables 25 and 26). This would indicate that the lakes were well mixed at the time of sampling. The ^{3}H concentrations were more variable, because of the large error associated with the measurements at these low levels.

In both 1981 and 1982, ^{3}H, ^{90}Sr, and uranium were lowest in Lake Superior (Table 27). ^{90}Sr was highest in Lake Huron and Lake Ontario, and uranium was highest in Lake Erie and Lake Ontario. ^{137}Cs concentrations were highest in Lake Superior and lowest in Lake Erie (Table 27); this is due to the low flux of sedimenting particles in the former and the high flux in the latter (38). ^{125}Sb concentrations were similar in all lakes and close to the minimum detectible level.

SIGNIFICANCE OF RADIOACTIVITY IN THE GREAT LAKES ECOSYSTEM

For virtually all of the waters of the Great Lakes, the concentrations of radionuclides present during 1981 and 1982 result in doses which are considerably less than the Agreement objective. Also, the observed concentrations generally meet jurisdictional drinking water requirements. Thus, these observed levels of radionuclides represent no concern with regard to human health.

Exceptions are waters within or near source control areas and in the vicinity of Port Hope Harbour. These have been described above.

In order to assess the human health significance of fission products, which have entered Lake Superior and Lake Huron from the atmosphere, Tracy and Prantl (86) examined radioactivity data collected between 1963 and 1980 for water, sediment, and biota samples from these two lakes.

They concluded that ^{90}Sr and ^{125}Sb appear to be removed from the water column primarily by radioactive decay, but settling plays a significant role for the removal of ^{137}Cs from the water. Nonetheless, 3-10% of ^{137}Cs persists in the water column for many years after its introduction.

Tracy and Prantl also noted that once deposited in the sediment, fission products remain at or near the sediment-water interface; this could facilitate re-entry of radionuclides into the water column and explain the persistence of ^{137}Cs in the water.

The concentration of ^{137}Cs in Great Lakes fish is several thousand times greater than the concentration in ambient water. Human consumption of fish is the most significant pathway of ^{137}Cs from the Upper Lakes to man. However, a health evaluation of the effects of consuming water and fish from the two lakes over the past 25 years showed no basis for concern.

Tracy and Prantl also concluded that the effects of nuclear power generation are not discernible against the background of fallout from nuclear weapons testing.

TABLE 25

OPEN LAKE DATA, 1981[a,b]

LAKE	SAMPLING LOCATION NORTH LATITUDE	SAMPLING LOCATION WEST LONGITUDE	SAMPLING DATE	DEPTH IN METRES	CONCENTRATION IN pCi/L ^{3}H	^{137}Cs	^{125}Sb	^{90}Sr	U, µg/L
SUPERIOR	46°44'36"	84°54'50"	July 17	1	166±74	0.045±0.005	<0.01	0.42±0.08	0.15±0.02
				61	<150	0.043±0.005	<0.01	0.43±0.06	0.16±0.02
	47°50'36"	88°20'12"	July 17	1	<150	0.045±0.005	<0.01	0.51±0.06	0.17±0.03
				244	174±74	0.056±0.005	<0.01	0.46±0.06	0.18±0.03
	46°49'40"	91°45'00"	July 17	1	<150	0.036±0.005	0.04±0.01	0.39±0.06	0.17±0.03
				58	162±74	0.037±0.005	0.02±0.01	0.40±0.06	0.18±0.03
	46°54'44"	86°10'02"	May 28	1	154±74	0.045±0.006	<0.01	0.27±0.06	0.15±0.02
				249	<150	0.048±0.006	<0.01	0.37±0.06	0.15±0.02
	48°12'58"	87°37'04"	May 26	1	223±74	0.062±0.006	0.02±0.01	0.37±0.06	0.14±0.02
				258	195±74	0.049±0.005	0.02±0.01	0.40±0.04	0.11±0.02
MICHIGAN	45°52'42"	85°28'30"	July 17	1	207±74	0.030±0.005	0.02±0.01	0.44±0.08	0.31±0.05
				37	252±74	0.043±0.005	0.02±0.01	0.63±0.12	0.35±0.05
	44°45'36"	86°58'00"	July 17	1	<150	0.033±0.006	0.02±0.01	---	0.42±0.06
				152	174±74	0.046±0.006	0.02±0.01	---	0.36±0.05
	42°23'00"	87°25'00"	July 8	1	174±74	0.040±0.005	<0.01	0.60±0.14	0.32±0.05
				92	<150	0.051±0.005	<0.01	0.61±0.16	0.44±0.07
	44°57'00"	87°36'20"	July 8	1	<150	0.031±0.005	0.04±0.01	0.35±0.13	0.43±0.07
HURON	45°01'01"	82°41'07"	May 30	1	292±74	0.036±0.005	0.02±0.01	0.73±0.13	0.24±0.04
				172	276±74	0.027±0.005	<0.01	0.73±0.10	0.26±0.04
	45°39'58"	83°43'39"	May 30	1	328±74	0.034±0.005	0.03±0.01	0.58±0.07	0.27±0.04
				118	264±74	0.034±0.005	0.03±0.01	0.64±0.10	0.28±0.04
	44°06'08"	82°06'57"	May 22	1	235±74	0.030±0.005	0.02±0.01	0.52±0.12	0.25±0.04
				95	383±76	0.038±0.006	0.04±0.01	0.77±0.14	0.25±0.04
	46°07'30"	82°53'25"	May 24	1	295±74	0.034±0.005	0.02±0.01	0.52±0.06	0.29±0.04
				27	261±74	0.043±0.005	0.02±0.01	0.64±0.06	0.24±0.04
	45°14'27"	80°52'36"	May 23	1	285±74	0.034±0.006	0.01±0.01	0.76±0.06	0.27±0.04
				76	245±74	0.030±0.005	0.05±0.01	0.89±0.07	0.23±0.04
ERIE	41°47'57"	82°49'33"	June 2	1	250±74	0.026±0.005	0.02±0.01	0.58±0.15	0.47±0.07
				9	323±74	0.028±0.005	0.03±0.01	0.54±0.12	0.51±0.08
	42°34'20"	79°36'09"	July 17	1	162±74	0.011±0.005	0.03±0.01	---	0.49±0.07
				56	171±74	0.014±0.006	0.03±0.01	0.65±0.07	0.37±0.06
	42°13'54"	80°52'05"	July 17	1	219±74	0.015±0.005	0.02±0.01	0.69±0.07	0.38±0.06
				22	254±74	0.025±0.006	0.04±0.01	0.55±0.13	0.38±0.06
ONTARIO	43°24'58"	79°23'55"	June 18	1	461±95	0.021±0.005	0.02±0.01	0.56±0.19	0.47±0.07
				103	456±76	0.020±0.005	<0.01	---	0.52±0.08
	43°43'00"	78°01'36"	June 16	1	270±76	0.027±0.006	<0.01	0.57±0.24	0.49±0.07
				125	364±76	0.025±0.005	0.04±0.01	---	0.46±0.07
	43°31'30"	76°55'33"	June 17	1	411±76	0.018±0.005	0.02±0.01	0.87±0.19	0.50±0.08
				209	233±76	0.042±0.005	0.02±0.01	0.76±0.18	0.55±0.08

a. Each grab sample = 50 L. ^{3}H analyses performed on 8 mL aliquots; U analyses on 5 mL aliquots; ^{137}Cs and ^{125}Sb on 45 L of sample; and ^{90}Sr on 3 L aliquots. The errors quoted for the β- and γ-counting results are the standard deviations of the net counting rates calculated from the total and background counting rates. The error of the uranium analyses is the expected standard deviation of a single analysis based on a series of replicate analyses carried out on a series of standard samples. Details about the analytical procedures are given in Reference (38).

b. Information from Reference (38).

b. Information from Reference (38).

TABLE 26

OPEN LAKE DATA, 1982[a,b]

LAKE	STATION LOCATION		SAMPLING DATE	DEPTH IN METRES	CONCENTRATION IN pCi/L				U, µg/L
	NORTH LATITUDE	WEST LONGITUDE			^{3}H	^{137}Cs	^{125}Sb	^{90}Sr	
Superior	48°13'00"	87°37'00"	June 4	1	<93	0.043 ± 0.006	<0.010	0.41 ± 0.04	0.09 ± 0.01
	46°54'54"	86°10'00"	May 11	1	<93	0.045 ± 0.006	<0.012	0.41 ± 0.02	0.07 ± 0.01
	47°16'15"	91°08'48"	May 18	1	250 ± 100	0.046 ± 0.006	<0.012	0 41 ± 0.06	0.08 ± 0.01
Huron	44°01'36"	82°10'00"	May 20	1	221 ± 100	0.030 ± 0.006	<0.013	0.73 ± 0.06	0.35 ± 0.05
	45°02'00"	82°41'36"	May 19	1	274 ± 100	0.032 ± 0.006	<0.014	0.72 ± 0.06	0.43 ± 0.06
Erie	41°48'32"	82°55'35"	May 29	1	355 ± 64	0.009 ± 0.005	<0.010	0.45 ± 0.10	0.57 ± 0.09
				10	361 ± 64	0.013 ± 0.005	<0.011	0.44 ± 0.10	0 48 ± 0.07
	42°16'19"	80°59'19"	May 27	1	250 ± 64	0.020 ± 0.007	0.012 ± 0.010	0.56 ± 0.06	0.73 ± 0.11
				22	303 ± 64	0.018 ± 0.006	0.022 ± 0.012	0.97 ± 0.12	0.67 ± 0.10
	43°35'18"	79°34'18"	May 26	1	338 ± 64	<0.006	0.019 ± 0.014	0.66 ± 0.10	0.50 ± 0.08
				55	361 ± 64	0.022 ± 0.007	0.019 ± 0.016	0.72 ± 0.06	0.59 ± 0.09
Ontario	43°25'00"	79°24'00"	June 17	1	186 ± 23	0.018 0.005	<0.013	0.89 ± 0.08	0.38 ± 0.06
				103	297 ± 29	0.018 ± 0.005	<0.012	0.54 ± 0.17	0.46 ± 0.07
	43°43'03"	78°01'35"	June 15	1	186 ± 23	<0.005	0.015 ± 0.012	0.73 ± 0.11	0.45 ± 0.07
				125	274 ± 29	0.026 ± 0.005	0.016 ± 0.012	0.73 ± 0.08	0.40 ± 0.06
	43°31'31"	76°55'32"	June 16	1	215 ± 29	0.023 ± 0.005	<0.012	0.98 ± 0.13	0.39 ± 0.06
				209	250 ± 29	0.083 ± 0.007	0.022 ± 0.014	0.85 ± 0.10	0.44 ± 0.07

a. Each grab sample = 50L. ^{3}H analyses performed on 8 mL aliquots; U analyses on 5 mL aliquots; ^{137}Cs and ^{125}Sb on 45 L of sample; and ^{90}Sr on 3 L aliquots. The errors quoted for the β- and γ-counting results are the standard deviations of the net counting rates calculated from the total and background counting rates. The error of the uranium analyses is the expected standard deviation of a single analysis based on a series of replicate analyses carried out on a series of standard samples. Details about the analytical procedures are given in Reference (38).

b. Information from Reference (75).

TABLE 27

MEAN RADIONUCLIDE CONCENTRATIONS IN THE GREAT LAKES - 1981 AND 1982[a]

YEAR	LAKE	CONCENTRATION IN pCi/L				U, μg/L
		^{3}H	^{137}Cs	^{125}Sb	^{90}Sr	
1981	Superior	168±74	0.047±0.005	0.02±0.01	0.40±0.04	0.16±0.02
	Michigan	180±74	0.039±0.005	0.02±0.01	0.53±0.10	0.38±0.05
	Huron	264±74	0.034±0.005	0.03±0.01	0.68±0.06	0.26±0.04
	Erie	230±74	0.020±0.005	0.03±0.01	0.60±0.07	0.43±0.07
	Ontario	366±76	0.026±0.005	0.02±0.01	0.69±0.18	0.50±0.08
1982	Superior	145±68	0.045±0.004	<0.012	0.41±0.03	0.08±0.01
	Huron	247±100	0.031±0.006	<0.014	0.73±0.06	0.39±0.05
	Erie	328±28	0.015±0.003	0.016±0.006	0.63±0.04	0.59±0.04
	Ontario	235±12	0.029±0.003	0.015±0.006	0.79±0.05	0.42±0.03

a. Information from References (38) and (75).

TABLE 28

DRINKING WATER INTAKES, 1981

INTAKE - SAMPLING LOCATION	TYPE OF SAMPLE	TYPE OF WATER	CONCENTRATION IN pCi/L[a,d]					REMARKS
			GROSS α	GROSS β	^{3}H	^{90}Sr	^{137}Cs	
LAKE MICHIGAN								
Charlevoix	Composite	Finished	<1 - 2	<2 - 4	-	<0.9 - <1	-	3 month samples, composited daily. No significant γ activity for all samples.
Petoskey	Composite	Finished	<1 - <3	<1 - 4	-	<0.8 - <1	-	
Lansing	Composite	Finished	<1 - 5	<2 - 4	-	<0.9 - <1	-	
Lake Township	Composite	Finished	<0.7 - <2	<2 - 2	-	<0.9 - <1	-	
Bridgman	Composite	Finished	<1 - <3	3.5 ± 2	-	<0.8 - <1	-	
South Haven	Composite	Finished	<0.8 - <2	<1 - 2	-	<0.8 - 1	-	
Benton Harbor	Composite	Finished	<1 - <3	3.2 ± 2	-	<0.8 - <1	-	
St. Joseph	Composite	Finished	<0.8 - <2	<1 - 3	-	<0.9 - 2	-	
LAKE HURON								
Kincardine	Composite	Raw	-	-	-	0.32	0.054	
		Treated	<1	4	400 ± 60	-	<15	Values calculated for 12 monthly composite samples. See footnotes "b" and "c".
Port Elgin	Composite	Raw	-	-	-	0.46	0.027	
		Treated	<1	2	830 ± 80	-	<15	Values calculated for 12 monthly composite samples. See footnotes "b" and "c".
Inverhuron Park	Composite	Treated	1	2	<130	-	-	Values calculated for 3 monthly composite samples. See footnotes "b" and "c".
MacGregor Point	Composite	Treated	<1	2	1090 ± 80	-	<15	Values calculated for 4 monthly composite samples. See footnotes "b" and "c".
DETROIT RIVER								
Detroit	Grab	Raw	0.2 ± 0.3	1.3 ± 0.8	350 ± 200	0.8 ± 0.6	-	^{3}H quarterly sampling and analysis, other parameters - one sample per year. ^{131}I =-0.1 ± 0.1 pCi/L (one sample).
Amherstburg	Composite	Treated	<1	2	260 ± 60	-	<15	Values calculated for 9 monthly composite samples. See footnotes "b" and "c".
LAKE ERIE								
Enrico Fermi	Composite	Raw	<0.6 - <1	<2 - 3	-	<0.9 - 1		3-month samples, composited daily. No significant γ activity for all samples.
Toledo	Grab	Raw	0.3 ± 0.3	3.0 ± 1.1	350 ± 200	0.2 ± 0.2		^{3}H-quarterly sampling and analysis. Other parameters - one sample per year. ^{131}I = 0.1 ± 0.1 pCi/L (one sample).
Harrow-Colchester	Composite	Treated	<1	2	250 ± 60	-	<15	Values calculated for 9 monthly composite samples. See footnotes "b" and "c".
Union	Composite	Treated	<1	2	240 ± 60	-	<15	Values calculated for 9 monthly composite samples. See footnotes "b" and "c".
Wheatley	Composite	Treated	<1	2	230 ± 60	-	<15	Values calculated for 8 monthly composite samples. See footnotes "b" and "c".
NIAGARA RIVER								
Niagara Falls, NY	Grab	Raw	0.1 ± 0.4	1.7 ± 1.1	380 ± 200	0.6 ± 0.3	-	^{3}H-quarterly sampling. Other parameters - one sample per year. ^{131}I = 0.2±0.1 pCi/L (one sample).
LAKE ONTARIO								
Port Hope	-	Treated	-	-	-	-	-	^{226}Ra <0.14 pCi/L . U = 1.5 μg/L
Ajax	Composite	Raw	-	-	-	0.41	0.027	
		Treated	1	3	530 ± 60		<15	Values calculated for 37 weekly composite samples. See footnotes "b" and "c".
Toronto	Composite	Raw	-	-	-	0.54	0.027	
		Treated	1	3	370 ± 55	-	<15	Values calculated for 37 weekly composite samples. See footnotes "b" and "c".
Ontario	Composite	Raw	<1.9 - <8	<2 - 6	278	-	<6 - <10	Also: ^{106}Ru, ^{95}Zr, ^{125}I, ^{7}Be
Oswego	Composite	Treated	<2 - 12	<2 - 8	285	-	<6 - <12	Also: ^{106}Ru, ^{95}Zr, Nb. No detectable activity.
Etobicoke	Composite	Treated	1	3	330 ± 50		<15	Values calculated for 37 weekly composite samples. See footnotes "b" and "c".

a. State of Michigan data - 2σ counting errors. Province of Ontario data - 1σ counting errors.
b. ^{60}Co, ^{134}Cs, and ^{131}I each <15 pCi/L for all samples.
c. Dissolved gross α and gross β values reported for non-volatile solids
d. Information from References (37, 39-43, 47, and 77).

TABLE 29

DRINKING WATER INTAKES, 1982

INTAKE - SAMPLING LOCATION	TYPE OF SAMPLE	TYPE OF WATER	CONCENTRATION IN pCi / L[a,d]					REMARKS
			GROSS α	GROSS β	^{3}H	^{90}Sr	^{137}Cs	
LAKE MICHIGAN								
Charlevoix	Composite	Finished	-	<1 - 3	200 ± 200	<1	-	^{3}H and ^{90}Sr - annual composite of 4 grab samples. Gross β - quarterly composite of grab samples.
Petoskey	Composite	Finished	-	2.2 ± 1.8	400 ± 200	<1	-	
Lansing	Composite	Finished	-	4.5 ± 2	<200	<1	-	
Lake Township	Composite	Finished	-	<1 - 3	200 ± 200	<1		
Bridgman	Composite	Finished	-	2.5 ± 1.5	<200	<1		
South Haven	Composite	Finished	-	<1 - 2	400 ± 200	<1	-	
Benton Harbor	Composite	Finished	-	2.8 ± 1.5	<200	<1		
St. Joseph	Composite	Finished	-	2.2 ± 1.5	<200	<1		
LAKE HURON								
Kincardine	Composite	Raw	-	-	-	0.24	0.027	
		Treated	<1	2	300 ± 60	-	<15	Values calculated for 9 monthly composite samples. See footnotes "b" and "c".
Port Elgin	Composite	Raw	-	-	-	0.38	0.081	
		Treated	1	2	950 ± 90	-	<15	Values calculated for 9 monthly composite samples. See footnotes "b" and "c".
DETROIT RIVER								
Detroit	Grab	Raw	-	-	400 ± 200	-	-	Quarterly sampling and analysis.
Amherstburg	Composite	Treated	1	2	260 ± 60	-	<15	Values calculated for 9 monthly composite samples. See footnotes "b" and "c".
LAKE ERIE								
Enrico Fermi	Composite	Finished	-	<1 - 3	200 ± 200	<1		^{3}H and ^{90}Sr - annual composite of 4 grab samples. Gross β quarterly composite of grab samples.
Toledo	Grab	Raw	-	-	300 ± 200	-	-	Quarterly sampling and analysis.
Harrow-Colchester	Composite	Treated	1	2	210 ± 60	-	<15	Values calculated for 9 monthly composite samples. See footnotes "b" and "c".
Union	Composite	Treated	<1	2	270 ± 100	-	<15	Values calculated for 2 monthly composite samples. See footnotes "b" and "c".
Wheatley	Composite	Treated	1	2	190 ± 60	-	<15	Values calculated for 9 monthly composite samples. See footnotes "b" and "c".
NIAGARA RIVER								
Niagara Falls, NY	Grab	Raw	-	-	200 ± 200		-	Quarterly sampling and analysis.
LAKE ONTARIO								
Port Hope		Treated	-	-	-	-	-	^{226}Ra <0.14 pCi/L . U = 1.4 μg/L
Ajax	Composite	Raw	-	-	-	0.38	0.054	
		Treated	1	3	590 ± 70	-	<15	Values calculated for 30 weekly composite samples. See footnotes "b" and "c".
Toronto	Composite	Raw	-	-	-	0.43	0.054	
		Treated	1	3	330 ± 60	-	<15	Values calculated for 30 weekly composite samples. See footnotes "b" and "c".
Ontario	Composite	Raw	<2 - <4	<2 - 4	<300 - 500	-	<6 - <10	
Oswego	Composite	Treated	<2 - <5	<2 - 5	<300 - <400	-	<7 - <11	
Etobicoke	Composite	Treated	1	3	290 ± 60	-	<15	Values calculated for 30 weekly composite samples. See footnotes "b" and "c".
Scarborough	Composite	Treated	2	3	290 ± 50	-	<15	Values calculated for 22 weekly composite samples. See footnotes "b" and "c".

a. State of Michigan data - 2σ counting errors. Province of Ontario data - 1σ counting errors.
b. ^{60}Co, ^{134}Cs and ^{131}I each <15 pCi/L for all samples.
c. Dissolved gross α and gross β values reported for non-volatile solids.
d. Information from References (39, 43, 47, 77, and 78).

TABLE 30

LAKE MICHIGAN - INSHORE SURFACE WATER, 1981[a,b]

NEARBY GENERATING STATION	STATION LOCATION	STATION NUMBER	CONCENTRATION IN pCi/L			REMARKS
			GROSS α	GROSS β	^{3}H	
Big Rock Point	Mt. McSauba Point	SB-1	<0.8-<2	<2	300 ± 200	
	0.8 km south	SB-2	<0.8-<2	<2-2	200 ± 200	
	BRP Plant	SB-3	<1-3	<1-7	310 ± 200	
	0.8 km north	SB-4	<1	<2-2	400 ± 200	
	Nine Mile Point	SB-5	<0.8-<2	2±2	250 ± 200	
	Charlevoix	-	-	-	400 ± 200	
Donald Cook	Weko Beach	SC-1	-	<3	250 ± 200	
	0.8 km south	SC-2	-	<2-3	350 ± 200	
	Cook Plant - Unit I	SC-3	-	<1-3	320 ± 200	
	Cook Plant - Unit II	SC-3a	-	<2-6	<200 - 500	
	0.8 km north	SC-4	-	3.0±2.5	300 ± 200	
	Chalet on Lake	SC-5	-	4.5±2.5	250 ± 200	
	Bridgman	-	-	-	530 ± 200	
Palisades	Covert Township Park	SP-2	-	<2-4	350 ± 200	
	Palisades Plant	SP-3	-	<2-6	330 ± 200	
	Van Buren State Park	SP-4	-	<2-4	300 ± 200	
	South Haven	SP-5	-	4.5±2.5	<200 - 300	
	Roadside Park	SP-6	-	3±2.5	<200	
	South Haven	-	-	-	430 ± 200	
Zion	0.6 km north of intake	0302003	<1.3-<1.6	4.1±2.1	<260 - 350	
	0.1 km south of intake	0302007	<1.5-2.8	4.3±2.1	<260 - 440	
	Town of Zion	-	-	-	370 ± 200	
(None)	Burns Ditch	BD-0	0.5±0.9	5.1±2.8	-	
	Indiana Harbor Canal	IHC-0	1.0±1.4	5.8±2.8	-	
	Lake, at East Chicago	LM-EC	0.8±1.3	4.0±2.7	-	
	Lake, at Gary	LM-G	0.4±0.9	4.1±2.6	-	
	Lake, at Hammond	LM H	0.8±1.3	4.4±2.7	-	
	Lake, at Michigan City	LM-M	0.3±0.8	3.0±2.5	-	
	Lake, at Whiting	LM-W	0.9±1.5	3.7±2.6	-	
Point Beach and Kewaunee	Two Creeks	-	-	-	380 ± 200	
	Kewaunee Effluent Canal	PBK-12	0.4±0.7	3.9±1.2	-390 - 270	^{90}Sr = 1.1±0.5 pCi/L.
	Point Beach Effluent Canal	PBK-10	0.3±0.8	3.3±1.3	-145 - 390	^{90}Sr = 0.8±0.5 pCi/L.
	Green Bay Pumping Station	PBK-13	0.0±0.7	2.8±1.3	-80 - 170	^{90}Sr = 0 9±0.5 pCi/L.

a. Information from References (40-46).
b. No significant or detectable γ-activity for samples so analyzed.

TABLE 31

LAKE MICHIGAN - INSHORE SURFACE WATER, 1982[a,b]

NEARBY GENERATING STATION	STATION LOCATION	STATION NUMBER	CONCENTRATION IN pCi/L			REMARKS
			GROSS α	GROSS β	^{3}H	
Big Rock Point	Mt. McSauba Point	SB-1	<3	<2-3	450 ± 200	
	0.8 km south	SB-2	<3	<2-3	250 ± 200	
	BRP Plant	SB-3	<2-<4	<2-7	<200 - 600	
	0.8 km north	SB-4	<3	<2-6	<200 ± 200	
	Nine Mile Point	SB-5	<2-<3	2.5±2	250 ± 200	
	Charlevoix	-	-	-	700 ± 200	
Donald Cook	Weko Beach	SC-1	-	<2-2	350 ± 200	
	0.8 km south	SC-2	-	<2-4	400 ± 200	
	Cook Plant - Unit I	SC-3	-	<2-8	200 - 600	
	Cook Plant - Unit II	SC-3a	-	<2-5	320 ± 200	
	0.8 km north	SC-4	-	2.5±2	250 ± 200	
	Chalet on Lake	SC-5	-	<2-2	250 ± 200	
	Bridgman	-	-	-	300 ± 200	
Palisades	Covert Township Park	SP-2		<2	250 ± 200	
	Palisades Plant	SP-3	-	<2-7	<200 ± 500	
	Van Buren State Park	SP-4	-	<2-2	350 ± 200	
	South Haven	SP-5	-	2.5±2	250 ± 200	
	Roadside Park	SP-6	-	<2-6	300 ± 200	
	South Haven	-	-	-	300 ± 200	
Zion	0 6 km north of intake	0302003	<1.3-1.3	4.2±1.9	<270 - 310	
	0.1 km south of intake	0302007	<1.2-2.3	4.0±1.9	<270 - 320	
	Town of Zion	-	-	-	350 ± 200	
(None)	Burns Ditch	BD-O	0.9±1.2	3.5±1.5	-	
	Indiana Harbor Canal	IHC-O	0.6±1.1	3.9±1.7	-	
	Lake, at East Chicago	LM-EC	0.0±0.9	1.9±1.0	-	
	Lake, at Gary	LM-G	0.2±1.0	2.7±1.3	-	
	Lake, at Hammond	LM-H	0.1±0.9	2.6±1.3	-	
	Lake, at Michigan City	LM-M	0 2±1.0	2.9±1.4	-	
	Lake, at Whiting	LM-W	0.0±0.9	1.8±1.0	-	
Point Beach and Kewaunee	Two Creeks	-	-	-	450 ± 200	
	Kewaunee Effluent Canal	0.1 mile east	0.4±0.7	3.1±1.2	-4 - 1380	^{90}Sr = 0.7±0.6 pCi/L.
	Point Beach Effluent Canal	0.1 mile east	0.6±0.8	4.6±1.3	-45 - 980	^{90}Sr = 0.7±0.5 pCi/L. ^{131}I: - 1.9 - 10.2 pCi/L.
	Green Bay Pumping Station	-	0.5±0.7	3.0±1.2	-11 - 570	^{90}Sr = 0.8±0.5 pCi/L.

a. Information from References (43-46, 77, and 78).
b. No significant or detectable γ-activity for samples so analyzed.

TABLE 32

LAKE ERIE - INSHORE SURFACE WATER, 1981 AND 1982[a,b]

NEARBY GENERATING STATION	STATION LOCATION	STATION NUMBER	YEAR	CONCENTRATION IN pCi/L	
				GROSS β	^{3}H
Fermi (under construction)	Fermi Plant	SE-9	1981	4.4±2.2	<200-500
	Toledo	-		-	280±200
	Monroe	-		-	330±200
Fermi (under construction)	Fermi Plant	SE-9	1982	<2-5	<200-500
	Toledo	-		-	300±200
	Monroe	-		-	400±200

a. Information from References (40-43, 77, and 78).
b. No significant or detectable γ-activity for samples so analyzed.

TABLE 33

LAKE ONTARIO - INSHORE SURFACE WATER[a,b]

NEARBY GENERATING STATION	STATION LOCATION	STATION NUMBER	YEAR	CONCENTRATION IN pCi/L			REMARKS
				GROSS α	GROSS β	^{3}H	
Nine Mile Point and Fitzpatrick	Demster Beach Road	3758-002	1981	<1.7-<9	<2.0-5	315	
	Scriba Inlet Canal	3767-003		-	-	205	Also: ^{137}Cs, ^{106}Ru, $^{95}ZrNb$
	Oswego	-		-	-	400±200	
Ginna	Ontario Discharge Canal	5857-002		-	-	290	Also: ^{137}Cs, ^{106}Ru, ^{95}Zr
-	Niagara Falls	3102-001		<1.8-<8	<3.0-4	280	
Nine Mile Point and Fitzpatrick	Demster Beach Road	3758-002	1982	<3-<5	<2-5	<300-<400	
	Scriba Inlet Canal	3767-003		-	-	325	Also: ^{137}Cs, ^{106}Ru, $^{95}ZrNb$, ^{134}Cs, ^{60}Co
	Oswego	-		-	-	400±200	
Ginna	Ontario Discharge Canal	5857-002		-	-	<200-2300	Also: ^{137}Cs, ^{106}Ru, $^{95}ZrNb$.
-	Niagara Falls	3102-001		<2-<4	<3-4	<300-400	

a. Information from References (37, 40-42, 77, and 78).
b. No detectable γ-activity for samples so analyzed.

TABLE 34

NORTH CHANNEL - SERPENT RIVER SURFACE WATER, 1980-1982[b,c]

DATE	FLOW (m^3/s)	CONCENTRATION IN pCi/L					^{238}U, µg/L
		GROSS α		GROSS β		^{226}Ra	
		DISSOLVED	UNDISSOLVED	DISSOLVED	UNDISSOLVED	DISSOLVED	
Feb. 28, 1980	10.7	98	5	11	5	3	
Apr. 29	53.3	5	1	4	1	1	
May 27	25.8	13	<1	9	<1	2	
June 25	12.2	8	2	8	1	2	
Sept. 26	9.20	8	1	9	1	2	
Oct. 26	17.9	5	1	6	<1	2	
Average for 1980[a]	17.7	-	-	-	-	1.58	
Jan. 25, 1981	6.05	13	1	10	3	3	<10
Feb. 25	17.5	10	1	5	1	<1	<10
May 25	15.5	6	1	4	1	1	3
June 27	14.6	8	1	8	1	2	<3
July 27	9.48	13	1	8	1	2	4
Aug. 27	3.24	5	3	6	1	2	<3
Oct. 27	15.0	13	1	6	<1	1	7
Nov. 27	8.79	8	1	8	<1	2	<3
Dec. 27	10.6	6	1	6	1	2	<3
Average for 1981[a]	16.4	-	-	-	-	1.56	-
Jan. 27, 1982	9.20	8	1	6	<1	1	<3
Feb. 27	6.60	14	<1	8	<1	2	6
Apr. 20	74.5	5	<1	3	<1	<1	3
May 18	44.9	9	<1	7	<1	2	3
June 21	12.2	9	1	6	<1	3	<3
July 26	5.89	6	<1	6	<1	3	<3
Aug. 26	2.89	11	1	7	<1	2	4
Sept. 27	30.1	8	<1	5	<1	1	3
Average for 1982[a]	24.7	-	-	-	-	1.43	-

a. Weighted average, taking into account the variable stream flow.
b. Station location: on Serpent River, at Hwy. 17 bridge, 8.4 km upstream from harbour. Station No. 140019-1.
c. Concentration data from Reference (47). Flow data from Reference (48).

TABLE 35

NORTH CHANNEL - INSHORE SURFACE WATER - SERPENT HARBOUR, 1981[a]

STATION NUMBER	STATION LOCATION		SAMPLING DATE	DISTANCE FROM SOURCE (km)	CONCENTRATION IN pCi/L			
	NORTH LATITUDE	WEST LONGITUDE			^{210}Pb	^{228}Ra	^{226}Ra	^{230}Th
274	46°12'15"	82°37'36"	May 20	0.4	0.6	0.5	1.8	<0.1
			June 15		0.9	0.4	1.3	<0 1
			July 21		0.3	0.4	2.1	<0.1
			Sept. 4		<0.2	0.5	1.2	0 3
			Oct. 3		<0.2	0.3	1.5	<0.1
279	46°12'12"	82°38'22"	May 20	1.4	0.7	0.5	1.9	<0 1
			June 15		0.5	0.2	1.2	<0.1
			July 21		0.4	0.3	1.4	<0.1
			Sept. 4		<0.2	0.2	1.1	<0.1
			Oct. 3		<0.2	0.4	1.1	<0.1
281	46°12'11"	82°39'00"	May 20	2.2	0.2	0.5	1.4	<0.1
			June 15		2.4	0.2	1.2	<0.1
			July 21		0.3	0.3	1.4	<0.1
			Sept. 4		<0.2	0.2	0.9	<0.1
			Oct. 3		<0.2	0.4	0.8	<0.1
285	46°12'04"	82°40'00"	May 20	-	0.1	0.4	1.6	<0.1
			June 15		1.2	0.3	1.4	<0.1
			July 21		0.4	<0.2	1.6	<0.1
			Sept. 4		0.3	0.2	0.4	<0.1
			Oct. 3		<0.2	<0.2	0.5	<0.1
286	46°11'45"	82°40'00"	May 20	3.7	0.2	0.3	1.0	<0.1
			June 15		0.3	0.2	0.6	<0.1
			July 21		0.2	<0.2	0.8	<0.1
			Sept. 4		<0.2	0.2	0.2	<0.1
			Oct. 3		<0.2	<0.2	0.7	<0.1
288	46°11'38"	82°41'04"	May 20	5.3	0.2	0.2	0.9	<0.1
			June 15		0.1	<0.2	0.5	<0.1
			July 21		<0.1	<0.2	0.3	<0 1
			Sept. 4		<0.2	<0.2	0.3	<0.1
			Oct. 3		0.3	<0.2	0.5	<0.1
290	46°11'27"	82°42'24"	May 20	-	0.3	0.2	0.6	<0.1
			June 15		2.2	<0.2	0.6	<0.1
			July 21		0.4	<0.2	0.3	<0.1
			Sept. 4		<0.2	<0.2	0.1	<0.1
			Oct. 3		<0.2	<0.2	0.2	<0.1
291	46°10'53"	82°42'24"	May 20	7.0	0.4	<0.2	0.2	<0.1
			June 15		0.2	<0.2	0.3	<0.1
			July 21		1.3	<0.2	0.2	<0.1
			Sept. 4		0.4	<0.2	<0.1	<0.1
			Oct. 3		0.4	<0.2	0.5	<0.1

a. Information from Reference (47).

TABLE 36

NORTH CHANNEL - INSHORE SURFACE WATER - SERPENT HARBOUR, 1982[a]

STATION NUMBER	STATION LOCATION		SAMPLING DATE	DISTANCE FROM SOURCE (km)	CONCENTRATION IN pCi/L			
	NORTH LATITUDE	WEST LONGITUDE			^{210}Pb	^{228}Ra	^{226}Ra	^{230}Th
274	46°12'15"	82°37'36"	May 13	0.4	0.3	0.5	1.0	<0.1
			July 13		0.1	0.6	1.8	<0.1
			Oct. 16		0.2	0.3	0.8	<0.1
			Nov. 13		0.2	<0.2	1.1	<0.1
279	46°12'12"	82°38'22"	May 13	1.4	0.3	0.6	0.9	<0.1
			July 13		0.2	0.5	2.5	<0.1
			Oct. 16		0.3	0.4	1.0	<0.1
			Nov. 13		0.2	<0.2	1.2	<0.1
281	46°12'11"	82°39'00"	May 13	2.2	0.4	0.5	1.0	<0.1
			July 13		0.2	<0.2	1.7	<0.1
			Oct. 16		0.1	0.4	1.1	<0.1
			Nov. 13		0.2	<0.2	1.4	<0.1
285	46°12'04"	82°40'00"	May 13		0.2	0.6	1.2	<0.1
			July 13		0.1	0.2	1.2	<0.1
			Oct. 16		0.3	0.3	1.4	<0.1
			Nov. 13		<0.1	<0.2	1.1	<0.1
286	46°11'45"	82°40'00"	May 13	3.7	0.3	0.3	0.9	<0.1
			July 13		<0.1	0.2	0.7	<0.1
			Oct. 16		0.2	0.2	0.8	<0.3
			Nov. 13		0.1	<0.2	0.9	<0.1
288	46°11'38"	82°41'04"	May 13	5.3	0.3	0.2	0.5	<0.1
			July 13		<0.1	<0.2	0.5	<0.1
			Oct. 16		0.1	0.3	0.4	<0.1
			Nov. 13		0.2	<0.2	0.4	<0.1
290	-	-	May 13	-	0.1	0.1	0.9	<0.1
			July 13		0.1	0.3	0.5	<0.1
			Oct. 16		0.2	<0.2	<0.1	<0.1
			Nov. 13		0.1	<0.2	0.1	<0.1
291	46°10'53"	82°42'24"	May 13	7.0	0.3	<0.2	0.2	<0.1
			July 13		<0.1	<0.2	0.1	<0.1
			Oct. 16		<0.1	<0.2	<0.1	<0.1
			Nov. 13		0.2	<0.2	<0.1	<0.1

a. Information from Reference (47).

TABLE 37

LAKE HURON INSHORE SURFACE WATER
DOUGLAS POINT AND BRUCE "A" NUCLEAR GENERATING STATIONS[a,b,c]
1981

STATION NUMBER[b]	NORTH LATITUDE	WEST LONGITUDE	SAMPLING DATE	CONCENTRATION IN pCi/L	
				^{3}H	^{90}Sr
113	44°18'24"	81°38'12"	May 4	290± 50	0.95±.15
			July 4	250± 40	0.69±.12
			Oct. 9	420± 60	0.61±.11
			Nov. 14	230± 50	0.91±.16
114	44°19'42"	81°37'24"	May 4	280± 50	0.92±.15
			July 4	160± 40	0.75±.13
			Oct. 9	380± 60	0.78±.13
			Nov. 14	260± 50	0.70±.12
115	44°20'48"	81°36'08"	May 4	350± 50	0.86±.15
			July 4	180± 40	0.51±.11
			Oct. 9	940± 80	0.76±.13
			Nov. 14	330± 50	0.70±.12
116	44°18'24"	81°36'42"	May 4	770± 70	0.94±.15
			July 4	220± 40	0.78±.13
			Oct. 9	560± 60	0.76±.13
			Nov. 14	300± 50	0.69±.12
117	44°20'09"	81°35'42"	May 4	1120± 80	0.90±.15
			July 4	270± 40	0.72±.12
			Oct. 9	1160± 90	0.84±.14
			Nov. 14	370± 50	0.66±.12
121	44°19'33"	81°36'50"	May 4	630± 60	1.11±.18
			July 4	220± 40	0.64±.12
			Oct. 9	1170±500	0.91±.16
			Nov. 14	370± 50	1.13±.18
122	44°20'02"	81°36'45"	May 4	330± 50	0.97±.16
			July 4	230± 40	0.73±.13
			Oct. 9	350± 60	0.53±.11
			Nov. 14	430± 50	0.82±.14
123	44°20'55"	81°34'23"	May 4	1450±100	1.02±.18
			July 4	720± 40	0.73±.13
			Oct. 9	5160±240	0.71±.13
			Nov. 14	4670±220	0.70±.12
364	44°19'03"	81°36'50"	May 4	860± 70	0.64±.11
			July 4	160± 40	0.77±.13
			Oct. 9	430± 60	0.82±.14
			Nov. 14	-	-
371	44°19'33"	81°36'27"	May 4	1010± 80	0.73±.13
			July 4	780± 40	0.77±.13
			Oct. 9	3130±160	0.70±.12
			Nov. 14	1040± 80	0.82±.14
372	44°20'36"	81°35'12"	May 4	930± 70	0.81±.13
			July 4	780± 40	0.72±.13
			Oct. 9	830± 80	0.85±.16
			Nov. 14	340± 50	1.02±.18

Table 37 - cont'd.

STATION NUMBER[b]	NORTH LATITUDE	WEST LONGITUDE	SAMPLING DATE	CONCENTRATION IN pCi/L	
				^{3}H	^{90}Sr
373	44°20'54"	81°35'21"	May 4	720± 70	0.74±.12
			July 4	190± 40	0.85±.15
			Oct. 9	-	-
			Nov. 14	350± 50	1.36±.26
456	44°19'11"	81°36'34"	May 4	1040± 80	0.81±.14
			July 4	250± 40	0.84±.15
			Oct. 9	340± 60	0.72±.14
			Nov. 14	280± 50	0.78±.14
458	44°19'46"	81°36'13"	May 4	1040± 80	0.72±.13
			July 4	200± 40	0.82±.15
			Oct. 9	540± 60	0.80±.15
			Nov. 14	-	-
459	44°20'09"	81°36'06"	May 4	820± 70	0.63±.13
			July 4	470± 40	0.73±.15
			Oct. 9	-	-
			Nov. 14	320± 50	1.21±.22
461	44°20'30"	81°35'29"	May 4	1020± 80	0.75±.14
			July 4	400± 40	0.87±.16
			Oct. 9	1620±110	0.90±.16
			Nov. 14	340± 50	2.09±.36
463	44°20'51"	81°34'44"	May 4	1400± 90	0.75±.13
			July 4	760± 40	0.79±.13
			Oct. 9	-	-
			Nov. 14	-	-
467	44°21'07"	81°34'44"	May 4	950± 80	0.79±.14
			July 4	380± 40	0.70±.12
			Oct. 9	6320±280	0.74±.15
			Nov. 14	4150±200	0.88±.15
469	44°20'55"	81°34'10"	May 4	174±110	0.66±.13
			July 4	1280± 50	0.86±.14
			Oct. 9	5390±250	0.89±.17
			Nov. 14	-	-

a. ^{60}Co, ^{137}Cs, and ^{134}Cs each <0.2 pCi/L at all stations except Station 121 (^{137}Cs = 0.23±0.03 pCi/L and ^{60}Co = 0.30±0.04 pCi/L on October 9) and Station 461 (^{137}Cs = 0.2 pCi/L on November 14).

b. A chart is available which shows the location of each station relative to the discharge channels from the Douglas Point and the Bruce "A" nuclear generating stations.

c. Information from Reference (47).

TABLE 38

LAKE HURON INSHORE SURFACE WATER
DOUGLAS POINT AND BRUCE "A" NUCLEAR GENERATING STATIONS[a,b,c]
1982

STATION NUMBER[b]	NORTH LATITUDE	WEST LONGITUDE	SAMPLING DATE	CONCENTRATION IN pCi/L	
				^{3}H	^{90}Sr
113	44°18'24"	81°38'12"	June 4	1380±110	0.70±.11
			Aug. 3	860± 80	0.70±.11
			Sept. 24	<140	0.78±.11
			Oct. 26	<140	0.62±.11
			Nov. 17	<140	0.68±.11
114	44°19'42"	81°37'24"	June 4	1300± 80	0.65±.14
			Aug. 3	810± 80	0.70±.11
			Sept. 24	140	0.68±.11
			Oct. 26	140	0.65±.11
			Nov. 17	140	0.70±.11
115	44°20'48"	81°36'08"	June 4	4590±220	0.84±.14
			Aug. 3	760± 80	0.68±.11
			Sept. 24	<140	0.62±.11
			Oct. 26	<140	0.68±.14
			Nov. 17	<140	0.76±.11
116	44°18'24"	81°36'42"	June 4	650± 50	0.76±.16
			Aug. 3	920± 80	0.78±.11
			Sept. 24	140± 50	0.59±.11
			Oct. 26	<140	0.76±.14
			Nov. 17	<140	0.78±.14
117	44°20'09"	81°35'42"	June 4	1410±110	0.59±.11
			Aug. 3	1190± 80	0.65±.11
			Sept. 24	490± 50	0.65±.11
			Oct. 26	<140	0.70±.11
			Nov. 17	490± 50	0.70±.14
121	44°19'33"	81°36'50"	June 4	970± 80	0.78±.14
			Aug. 3	1080± 80	0.68±.11
			Sept. 24	150± 50	0.59±.08
			Oct. 26	620± 50	0.68±.11
			Nov. 17	680± 50	0.65±.11
122	44°20'02"	81°36'45"	June 4	1000± 80	0.89±.16
			Aug. 3	760± 80	0.70±.14
			Sept. 24	180± 50	0.62±.11
			Oct. 26	<140	0.68±.11
			Nov. 17	760± 80	0.70±.14
123	44°20'55"	81°34'23"	June 4	2970±160	0.51±.16
			Aug. 3	2000±110	0.78±.14
			Sept. 24	2220±140	0.68±.11
			Oct. 26	1650±110	0.65±.11
			Nov. 17	1970±110	0.81±.14
364	44°19'03"	81°36'50"	June 4	590± 50	0.68±.11
			Aug. 3	1380±110	0.78±.14
			Sept. 24	<140	0.65±.08
			Oct. 26	510± 50	0.59±.11
			Nov. 17	<140	0.78±.14
371	44°19'33"	81°36'27"	June 4	540± 50	0.59±.08
			Aug. 3	1650±110	0.68±.11
			Sept. 24	270± 50	0.76±.11
			Oct. 26	1320± 80	0.68±.11
			Nov. 17	6490±270	0.65±.11

Table 38 - cont'd.

STATION NUMBER[b]	NORTH LATITUDE	WEST LONGITUDE	SAMPLING DATE	CONCENTRATION IN pCi/L	
				^{3}H	^{90}Sr
372	44°20'36"	81°35'12"	June 4	1350±110	0.57±.08
			Aug. 3	1220± 80	0.70±.11
			Sept. 24	380± 50	0.76±.11
			Oct. 26	<140	0.62±.14
			Nov. 17	<140	0.73±.14
373	44°20'54"	81°35'21"	June 4	1650±110	0.70±.11
			Aug. 3	890± 80	0.65±.14
			Sept. 24	460± 50	0.62±.11
			Oct. 26	300± 50	0.65±.14
			Nov. 17	<140	0.70±.11
456	44°19'11"	81°36'34"	June 4	350± 50	0.76±.11
			Aug. 3	1350±110	0.59±.14
			Sept. 24	300± 50	0.65±.11
			Oct. 26	300± 50	0.70±.14
			Nov. 17	<140	0.73±.14
458	44°19'46"	81°36'13"	June 4	650± 80	0.57±.08
			Aug. 3	970± 80	0.65±.11
			Sept. 24	320± 50	0.70±.11
			Oct. 26	<140	0.68±.16
			Nov. 17	230± 50	0.73±.14
459	44°20'09"	81°36'06"	June 4	1240± 80	0.76±.11
			Aug. 3	2000±110	0.73±.11
			Sept. 24	1190± 80	0.70±.11
			Oct. 26	<140	0.70±.11
			Nov. 17	350± 50	0.70±.11
461	44°20'30"	81°35'29"	June 4	1590±110	0.73±.11
			Aug. 3	810± 80	0.73±.11
			Sept. 24	320± 50	0.70±.11
			Oct. 26	<140	0.70±.11
			Nov. 17	270± 50	0.62±.11
466	44°21'04"	81°35'03"	June 4	5410±240	0.46±.08
			Aug. 3	1050± 80	0.54±.16
			Sept. 24	300± 50	0.76±.14
			Oct. 26	650± 50	0.65±.11
			Nov. 17	<140	0.70±.11
467	44°21'07"	81°34'44"	June 4	3780±190	0.54±.08
			Aug. 3	1840±110	0 78±.14
			Sept. 24	680± 80	0.68±.11
			Oct. 26	1840±110	0.68±.11
			Nov. 17	<140	0.68±.11
469	44°20'55"	81°34'10"	June 4	2700±140	0.57±.08
			Aug. 3	4860±270	0.62±.11
			Sept. 24	2970±270	0.62±.11
			Oct. 26	2700±270	0.73±.11
			Nov. 17	2240±140	0.78±.14

a. ^{60}Co, ^{137}Cs, and ^{134}Cs each <0.2 pCi/L at all stations.
b. A chart is available which shows the location of each station relative to the discharge channels from the Douglas Point and the Bruce "A" nuclear generating stations.
c. Information from Reference (47).

TABLE 39

PICKERING "A" SOURCE CONTROL AREA[a]
1981

STATION LOCATION		STATION NUMBER	SAMPLING DATE	CONCENTRATION IN pCi/L			
NORTH LATITUDE	WEST LONGITUDE			GROSS α	GROSS β	^{3}H	^{90}Sr
43°48'33"	79°04'44"	1659	May 13	1	2	490 ± 60	0.65 ± .12
			July 2	<1	3	1080 ± 80	0.74 ± .12
			Sept. 8	3	4	590 ± 60	0.84 ± .17
			Nov. 9	<2	3	290 ± 50	1.00 ± .16
43°48'25"	79°04 32"	1660	May 13	1	3	500 ± 60	0.64 ± .12
			July 2	<1	3	800 ± 70	0.81 ± .13
			Sept. 8	<2	3	870 ± 70	0.87 ± .16
			Nov. 9	<2	3	350 ± 50	0.78 ± .14
43°48'35"	79°05'03"	1661	May 13	<1	3	430 ± 50	0.70 ± .13
			July 2	<1	3	1220 ± 80	0.84 ± .14
			Sept. 8	<2	3	250 ± 50	0.90 ± .16
			Nov. 9	<2	4	240 ± 50	0.88 ± .16
43°48'25"	79°05'00"	1662	May 13	<1	3	440 ± 60	0.93 ± .16
			July 2	1	3	720 ± 60	0.89 ± .14
			Sept. 8	<2	4	380 ± 50	0 74 ± .16
			Nov. 9	<2	2	250 ± 50	0.84 ± .15
43°48'15"	79°04'51"	1663	May 13	1	2	510 ± 60	0.80 ± .15
			July 2	1	3	460 ± 60	0.81 ± .15
			Sept. 8	<2	3	310 ± 50	0.80 ± .14
			Nov. 9	<2	3	270 ± 50	0.86 ± .16
43°48'09"	79°04'40"	1664	May 13	<1	3	440 ± 60	0.80 ± .14
			July 2	2	2	350 ± 50	0.90 ± .14
			Sept. 8	<2	4	420 ± 60	0.64 ± .12
			Nov. 9	<2	3	220 ± 40	0.85 ± .17
43°48'07"	79°04'08"	1665	May 13	<1	3	460 ± 60	0.66 ± .12
			July 2	<1	2	420 ± 50	1.00 ± .18
			Sept. 8	<2	4	530 ± 60	0.78 ± .15
			Nov. 9	<2	3	290 ± 50	1.02 ± .17
43'48'19"	79°03'52"	1666	May 13	<1	3	840 ± 70	0.88 ± .15
			July 2	<1	3	430 ± 50	0.94 ± .18
			Sept. 8	<2	3	470 ± 60	0.85 ± .16
			Nov. 9	<2	3	540 ± 60	0.78 ± .14

a. Information from Reference (47).

TABLE 40

PICKERING "A" SOURCE CONTROL AREA[a]
1982

STATION LOCATION		STATION NUMBER	SAMPLING DATE	CONCENTRATION IN pCi/L			
NORTH LATITUDE	WEST LONGITUDE			GROSS α	GROSS β	^{3}H	^{90}Sr
43°48'33"	79°04'44"	1659	May 6	<2	3	2350 ± 140	0.62 ± .11
			June 25	<2	3	350 ± 50	0.81 ± .14
			Aug. 6	<1	4	1510 ± 110	0.84 ± .14
			Sept. 22	<1	4	1570 ± 110	0.78 ± .11
			Oct. 25	<2	3	1050 ± 80	0.59 ± .08
			Dec. 2	<2	4	1300 ± 80	0.89 ± .11
43°48'25"	79°04'32"	1660	May 6	<2	4	1540 ± 110	0.65 ± .11
			June 25	<2	2	210 ± 50	0.86 ± .14
			Aug. 6	<1	4	760 ± 80	0.95 ± .11
			Sept. 22	<1	3	1220 ± 80	0.73 ± .14
			Oct. 25	<2	3	950 ± 80	0.68 ± .11
			Dec. 2	<2	4	4320 ± 270	0.92 ± .14
43°48'35"	79°05'03"	1661	May 6	<2	3	1540 ± 110	0.70 ± .11
			June 25	<2	4	430 ± 50	0.84 ± .14
			Aug. 6	<1	3	840 ± 80	0.68 ± .11
			Sept. 22	1	3	1220 ± 80	0.89 ± .14
			Oct. 25	<2	4	730 ± 80	0.78 ± .27
			Dec. 2	<2	4	1320 ± 80	0.91 ± .14
43°48'25"	79°05'00"	1662	May 6	<2	4	1300 ± 80	0.59 ± .11
			June 25	<2	3	180 ± 50	0.70 ± .11
			Aug. 6	<1	3	540 ± 50	0.76 ± .11
			Sept. 22	<1	4	950 ± 80	0.81 ± .11
			Oct. 25	<2	3	620 ± 50	0.78 ± .14
			Dec. 2	<2	5	1220 ± 80	0.81 ± .11
43°48'15"	79°04'51"	1663	May 6	<2	3	730 ± 50	0.92 ± .14
			June 25	<2	4	620 ± 50	0.86 ± .14
			Aug. 6	<1	4	620 ± 50	0.73 ± .11
			Sept. 22	<1	4	1000 ± 80	0.73 ± .11
			Oct. 25	<2	4	380 ± 50	0.73 ± .14
			Dec. 2	<2	3	1080 ± 80	0.89 ± .14
43°48'09"	79°04'40"	1664	May 6	<2	4	810 ± 50	0.73 ± .11
			June 25	<2	3	970 ± 80	0.68 ± .11
			Aug. 6	<1	3	490 ± 50	0.76 ± .14
			Sept. 22	2	4	840 ± 80	0.65 ± .11
			Oct. 25	<2	3	430 ± 50	0.78 ± .11
			Dec. 2	<2	4	680 ± 50	0.78 ± .11
43°48'07"	79°04'08"	1665	May 6	<2	3	410 ± 50	0.65 ± .11
			June 25	<2	4	780 ± 80	0.86 ± .14
			Aug. 6	-	-	-	-
			Sept. 22	2	4	140	0.68 ± .11
			Oct. 25	<2	3	570 ± 50	0.76 ± .14
			Dec. 2	<2	4	240 ± 50	0.76 ± .11
43°48'19"	79°03'52"	1666	May 6	<2	3	430 ± 50	0.70 ± .14
			June 25	<2	2	810 ± 80	0.76 ± .11
			Aug. 6	<1	3	210 ± 50	0.84 ± .14
			Sept. 22	1	3	470	0.76 ± .11
			Oct. 25	<2	3	570 ± 50	0.76 ± .14
			Dec. 2	<2	3	270 ± 50	0.89 ± .14

a. Information from Reference (47).

TABLE 41

LAKE ONTARIO SURFACE WATERS - PORT HOPE HARBOUR - 1981[a]

GENERAL AREA	STATION LOCATION	STATION NUMBER	SAMPLING DATE	CONCENTRATION IN pCi/L					U µg/L
				GROSS α		GROSS β		^{226}Ra	
				DISSOLVED	UNDISSOLVED	DISSOLVED	UNDISSOLVED	DISSOLVED	
Inside Port Hope Harbour	50 yd opposite stormwater discharge	6-01-2015	May 28	930	2	180	27	1	650
			June 18	87	1	14	8	1	61
			Aug. 10	26	1	6	2	1	15
			Aug. 21	75	<1	11	1	<1	42
			Sept. 24	23	2	6	2	1	14
	100 yd opposite stormwater discharge	6-01-2016	May 28	730	2	140	26	1	510
			June 18	90	1	16	8	1	63
			Aug. 10	30	<1	4	1	1	17
			Aug. 21	73	<1	11	1	<1	42
			Sept. 24	35	1	6	2	1	20
	50 yd opposite cooling water discharge	6 01-2014	May 28	720	4	120	27	1	500
			June 18	90	2	12	17	1	51
			Aug. 10	32	1	4	3	1	18
			Aug. 21	59	<1	12	1	1	33
			Sept. 24	38	3	5	3	1	23
	Entrance to turning basin	6-01-2013	May 28	540	1	100	27	<1	380
			June 18	49	1	7	2	1	30
			Aug. 10	26	1	6	3	1	14
			Aug. 21	63	<1	10	1	1	36
			Sept. 24	34	3	4	4	1	18
	South of Crane dock	6-01-2012	May 28	530	1	77	16	<1	310
			June 18	19	<1	3	1	1	11
			Aug. 10	17	<1	5	1	1	10
			Aug. 21	59	<1	9	2	<1	33
			Sept. 24	12	<1	3	<1	<1	6
Outside Port Hope Harbour	50 yd west of harbour mouth	6-01-2011	May 28	12	<1	3	<1	<1	7
			June 18	8	<1	3	<1	<1	5
			Aug. 10	4	<1	3	<1	<1	3
			Aug. 21	28	<1	5	<1	<1	15
			Sept. 24	2	<1	2	<1	<1	3
	50 yd east of harbour mouth	6-01 2010	May 28	7	<1	4	1	<1	4
			June 18	15	<1	4	<1	1	9
			Aug. 10	2	<1	3	<1	<1	<3
			Aug. 21	3	<1	3	<1	<1	<3
			Sept. 24	1	<1	3	<1	<1	<3
	100 yd south of harbour mouth	6-01-2009	May 28	85	1	11	3	<1	49
			June 18	10	<1	2	<1	<1	7
			Aug. 10	2	<1	3	<1	<1	<3
			Aug. 21	2	<1	3	<1	<1	<3
			Sept. 24	1	<1	3	<1	<1	<3

a. Information from Reference (47).

TABLE 42

LAKE ONTARIO SURFACE WATERS - PORT HOPE HARBOUR - 1982[a]

GENERAL AREA	STATION LOCATION	STATION NUMBER	SAMPLING DATE	CONCENTRATION IN pCi/L					U µg/L
				GROSS α		GROSS β		^{226}Ra	
				DISSOLVED	UNDISSOLVED	DISSOLVED	UNDISSOLVED	DISSOLVED	
Inside Port Hope Harbour	50 yd opposite stormwater discharge	6-01-2015	May 26	138	4	13	19	<1	96
			June 24	24	<1	6	2	<1	17
			July 22	92	2	14	6	<1	57
			Sept. 18	32	4	7	5	1	18
	100 yd opposite stormwater discharge	6-01-2016	May 26	143	4	13	16	<1	100
			June 24	23	2	7	3	1	16
			July 22	84	<1	14	1	<1	52
			Sept. 18	32	4	8	5	1	18
	50 yd opposite cooling water discharge	6 01-2014	May 26	157	5	13	18	<1	95
			June 24	35	1	6	3	<1	20
			July 22	89	<1	15	6	<1	52
			Sept. 18	38	9	9	9	2	19
	Entrance to turning basin	6 01-2013	May 26	173	3	1	16	<1	110
			June 24	30	<1	6	2	<1	17
			July 22	70	1	11	4	<1	41
			Sept. 18	38	8	9	8	2	22
	South of Crane dock	6-01-2012	May 26	95	1	10	7	<1	67
			June 24	8	<1	2	<1	<1	3
			July 22	20	<1	3	<1	<1	12
			Sept. 18	22	2	4	2	2	12
	Eldorado cooling water intake	-	June 30	19	1	4	2	<1	11
			Oct. 19-20	13	3	4	4	<1	7
			Nov. 24	70	3	9	6	<1	42
			Dec. 22	594	19	59	17	4±0.3	350
	UF_6 discharge	-	June 30	38	2	8	9	<1	23
			Oct. 19-20	30	4	5	9	<1	21
			Nov. 24	49	3	12	8	<1	27
			Dec. 22	540	32	46	49	4±0.3	330
	UO_2/UO_3 discharge	-	June 30	49	2	11	5	<1	31
			Oct. 19-20	108	5	15	14	<1	67
			Nov. 24	97	6	15	2	1±0.3	55
			Dec. 22	513	35	78	46	3±0.3	310
	South UO_2 discharge	-	June 30	35	2	5	4	<1	19
			Nov. 24	184	2	19	11	<1	110
Outside Port Hope Harbour	50 yd west of harbour mouth	6-01-2011	May 26	4	<1	3	<1	<1	3
			June 24	3	<1	3	<1	<1	3
			July 22	16	<1	3	<1	<1	9
			Sept. 18	27	1	5	<1	<1	16
	50 yd east of harbour mouth	6-01-2010	May 26	68	1	6	6	<1	43
			June 24	4	<1	1	<1	<1	23
			July 22	14	<1	26	<1	<1	10
			Sept. 18	12	<1	2	<1	<1	8
	100 yd south of harbour mouth	6-01-2009	May 26	32	<1	4	1	<1	21
			June 24	12	<1	17	<1	<1	4
			July 22	26	<1	5	<1	<1	16
			Sept. 18	19	2	7	3	<1	10

a. Information from Reference (47).

TABLE 43

LAKE ONTARIO SURFACE WATERS OFF WELCOME AND PORT GRANBY DUMPS - 1981[a]

GENERAL AREA	STATION LOCATION	STATION NUMBER	SAMPLING DATE	CONCENTRATION IN pCi/L					U µg/L
				GROSS α		GROSS β		^{226}Ra	
				DISSOLVED	UNDISSOLVED	DISSOLVED	UNDISSOLVED	DISSOLVED	
Off Welcome Dump	50 m south of discharge	6-01-2006	May 28	27	<1	7	1	<1	16
			June 18	7	<1	3	<1	<1	4
			Aug. 10	2	<1	3	<1	<1	<3
			Aug. 27	2	<1	3	<1	<1	<3
			Sept 24	1	<1	3	<1	<1	<3
	100 m southeast of discharge	6-01-2007	May 28	28	<1	7	1	<1	16
			June 18	7	<1	3	<1	<1	4
			Aug. 10	<1	<1	2	<1	<1	<3
			Aug. 27	1	<1	2	<1	<1	<3
			Sept. 24	1	<1	3	<1	<1	<3
	100 m southwest of discharge	6 01-2008	May 28	23	<1	6	<1	<1	14
			June 18	1	<1	3	<1	<1	<3
			Aug. 10	1	<1	2	<1	<1	<3
			Aug. 27	<1	<1	2	<1	<1	<3
			Sept. 24	1	<1	3	<1	<1	<3
Off Port Granby Dump	50 m south of East Gorge	6-01-2001	May 28	4	<1	4	<1	<1	3
			June 18	1	<1	2	<1	<1	<3
			Aug. 10	1	<1	2	<1	<1	<3
			Aug. 27	<1	<1	3	<1	<1	<3
			Sept. 24	1	<1	3	<1	<1	<3
	100 m southeast of East Gorge	6 01-2002	May 28	4	<1	3	<1	<1	<3
			June 18	1	<1	2	<1	<1	<3
			Aug. 10	1	<1	2	<1	<1	<3
			Aug. 27	1	<1	3	<1	<1	<3
			Sept. 24	1	<1	3	<1	<1	<3
	50 m south of of West Gorge	6-01-2003	May 28	4	<1	3	<1	<1	3
			June 18	1	<1	2	<1	<1	<3
			Aug. 10	1	<1	2	<1	<1	<3
			Aug. 27	1	<1	2	<1	<1	<3
			Sept. 24	1	<1	3	<1	<1	<3
	100 m southwest of West Gorge	6 01-2004	May 28	4	<1	2	<1	<1	3
			June 18	1	<1	2	<1	<1	<3
			Aug. 10	1	<1	2	<1	<1	<3
			Aug. 27	1	<1	3	<1	<1	<3
			Sept. 24	2	<1	4	<1	<1	<3

a. Information from Reference (47).

TABLE 44

LAKE ONTARIO SURFACE WATER OFF WELCOME AND PORT GRANBY DUMPS - 1982[a]

GENERAL AREA	STATION LOCATION	STATION NUMBER	SAMPLING DATE	CONCENTRATION IN pCi/L					U µg/L
				GROSS α		GROSS β		^{226}Ra	
				DISSOLVED	UNDISSOLVED	DISSOLVED	UNDISSOLVED	DISSOLVED	
Off Welcome Dump	50 m south of discharge	6-01-2006	May 28	1	<1	3	<1	<1	<3
			June 26	3	<1	24	<1	<1	<3
			July 24	6	<1	2	<1	<1	4
			August 8	14	<1	2	<1	<1	10
	100 m southeast of discharge	6-01-2007	May 28	3	<1	2	<1	<1	<3
			June 26	3	<1	3	<1	<1	<3
			July 24	6	<1	3	<1	<1	<4
			August 8	8	<1	2	<1	<1	5
	100 m southwest of discharge	6-01-2008	May 28	3	<1	2	<1	<1	<3
			June 26	3	<1	3	<1	<1	<3
			July 24	7	<1	4	<1	<1	4
			August 8	8	<1	3	<1	<1	5
Off Port Granby Dump	50 m south of East Gorge	6-01-2001	May 28	3	<1	2	<1	<1	<3
			June 26	3	<1	2	<1	<1	<3
			July 24	4	<1	3	<1	<1	<3
			August 8	10	<1	3	<1	<1	6
	100 m southeast of East Gorge	6-01-2002	May 28	1	<1	2	<1	<1	<3
			June 26	3	<1	4	<1	<1	<3
			July 24	3	<1	2	<1	<1	<3
			August 8	8	<1	2	<1	<1	5
	50 m south of West Gorge	6-01-2003	May 28	1	<1	2	<1	<1	<3
			June 26	2	<1	2	<1	<1	<3
			July 24	5	<1	3	<1	<1	<3
			August 8	10	<1	4	<1	<1	6
	100 m southwest of West Gorge	6-01-2004	May 28	1	<1	2	<1	<1	<3
			June 26	1	<1	2	<1	<1	<3
			July 24	2	<1	2	<1	<1	<3
			August 8	8	<1	2	<1	<1	5

a. Information from Reference (47).

TABLE 45

RADIONUCLIDE LEVELS IN GREAT LAKES FISH, 1981[c]

LAKE	COLLECTION LOCATION	COLLECTION DATE	TYPE OF FISH	MASS OF WHOLE FISH, kg	CONCENTRATION (wet weight)		
					^{137}Cs (pCi/kg)	^{226}Ra (pCi/kg)	U (μg/kg)
Huron	Off Blind River	July 7-11	Walleye	5.14	252 ± 13	1.5 ± 0.5	-
				5.63	243 ± 15	1.1 ± 0.3	0.5 ± 0.1
				4.75	328 ± 8	1.3 ± 0.3	0.5 ± 0.1
				2.17	218 ± 12	1.8 ± 0.3	0.5 ± 0.1
				2.22	230 ± 12	1.1 ± 0.3	0.5 ± 0.1
				1.67	316 ± 8	1.7 ± 0.4	0.4 ± 0.1
			Sturgeon	2.03	62 ± 5	2.6 ± 0.4	2.0 ± 0.3
				8.48	105 ± 6	4.0 ± 0.4	1.4 ± 0.2
				10.40	87 ± 8	4.3 ± 0.4	3.0 ± 0.4
				37.40	109 ± 8	2.4 ± 0.3	2.0 ± 0.3
Ontario	Ganaraska River	April 9	Rainbow trout	3.17	43 ± 5	0.8 ± 0.2	0.4 ± 0.1
				3.55	34 ± 4	0.5 ± 0.2	1.2 ± 0.2
				4.41	48 ± 3	0.4 ± 0.2	0.3 ± 0.1
				5.33	36 ± 4	1.1 ± 0.2	0.9 ± 0.2
				4.50	40 ± 4	0.7 ± 0.2	0.4 ± 0.1
				2.78	33 ± 3	0.5 ± 0.2	0.4 ± 0.1
				2.20	39 ± 3	0.5 ± 0.2	0.3 ± 0.1
				4.54	28 ± 3	0.4 ± 0.2	0.3 ± 0.1
				4.77	40 ± 3	0.4 ± 0.2	0.3 ± 0.1
				1.52	33 ± 3	0.6 ± 0.2	0.3 ± 0.1
	Near Ginna N.G.S.	Oct. 27	-	-	49 ± 16[a]	-	-
	Near Nine Mile Point N.G.S.	May 20	Top feeder	-	58 ± 12[b]	-	-

a. ^{134}Cs <14 pCi/kg and ^{106}Ru <70 pCi/kg.
b. ^{134}Cs <9 pCi/kg and ^{106}Ru <70 pCi/kg.
c. Information from References (37-38).

TABLE 46

RADIONUCLIDE LEVELS IN GREAT LAKES FISH, 1982[c]

LAKE	COLLECTION LOCATION	TYPE OF FISH	MASS OF WHOLE FISH, kg	CONCENTRATION (wet weight)	
				^{137}Cs (pCi/kg)	^{226}Ra (pCi/kg)
Huron	North Channel	Lake trout	2.59	236 ± 5	0.6 ± 0.2
			-	217 ± 5	0.5 ± 0.3
			-	214 ± 4	<0.2
Erie	Western Basin	Walleye	2.51	28 ± 3	1.2 ± 0.2
			2.24	24 ± 2	1.9 ± 0.2
			-	18 ± 2	1.1 ± 0.2
Ontario	Cobourg	Rainbow trout	-	41 ± 3	0.4 ± 0.2
		Lake trout	-	44 ± 3	<0.2
			-	41 ± 3	<0.2
			-	39 ± 3	0.3 ± 0.1
	Niagara-on-the-Lake	Lake trout	2.19	45 ± 3	0.7 ± 0.2
			-	61 ± 5	0.7 ± 0.2
			-	34 ± 2	0.4 ± 0.2
			-	33 ± 3	<0.2
	Near Oswego	-	-	53 ± 11[a]	-
		-	-	37 ± 9[b]	-

a. ^{134}Cs <9 pCi/kg, ^{106}Ru <40 pCi/kg, and ^{40}K = 2500±200 pCi/kg. Date of collection - June 12.
b. ^{134}Cs <8 pCi/kg, ^{106}Ru <40 pCi/kg, and ^{40}K = 2090±190 pCi/kg. Date of collection - October 11.
c. Information from Reference (75-76).

7. Atmospheric Monitoring Programs in the Great Lakes Basin

This chapter describes the routine atmospheric monitoring programs conducted in the Great Lakes basin by the U.S. Environmental Protection Agency, the New York Department of Health, the Wisconsin Department of Health and Social Services, and the Canada Department of National Health and Welfare. Results from these programs for 1981 and 1982 are presented, along with a discussion of the significance of these results. Special studies undertaken by National Health and Welfare are also described.

ROUTINE MONITORING PROGRAMS

ENVIRONMENTAL RADIATION AMBIENT MONITORING SYSTEM (40-42, 51, 77, 78)

In the United States, environmental radiation data are compiled and distributed by EPA's Office of Radiation Programs, Eastern Environmental Radiation Facility, Montgomery, Alabama. Data are collected through the Environmental Radiation Ambient Monitoring System (ERAMS) and published quarterly in the report series, "Environmental Radiation Data".

ERAMS was established in 1973. The nationwide network of sampling stations provides air, surface water, drinking water, as well as milk samples from which environmental radiation levels are derived. The major emphasis is on the identification of trends in the accumulation of long-lived radionuclides in the environment. Sampling locations are selected to provide wide population coverage.

The stations provide information about:

1. Fallout from nuclear weapons tests.
2. Releases from nuclear power reactors, fuel fabrication facilities, and reprocessing plants.
3. Natural background levels.

The analyses performed on air particulate and precipitation samples provide an indication of the general impact of all contributing sources on environmental levels of radiation.

Airborne particulate samples are presently being collected on a continuous basis at more than 40 locations in the United States, six of which are located in or near the Great Lakes basin (Table 47). Filters from air samplers are changed twice weekly. Analyses are performed for gross ß and, if the gross ß count is greater than 1 pCi/m^3, a γ-scan is performed. Analyses are also performed on quarterly composites for ^{238}Pu, ^{239}Pu, ^{234}U, ^{235}U, and ^{238}U.

TABLE 47

LOCATION OF ATMOSPHERIC MONITORING
STATIONS IN THE GREAT LAKES BASIN

UNITED STATES - ENVIRONMENTAL RADIATION AMBIENT MONITORING SYSTEM

Air Particulates	Precipitation
Chicago, Illinois	Chicago, Illinois
Lansing, Michigan	Lansing, Michigan
Niagara Falls, New York	Niagara Falls, New York
Syracuse, New York	
Toledo, Ohio	
Madison, Wisconsin	

STATE OF NEW YORK - DEPARTMENT OF HEALTH

Location	Nearby Source
Cattaraugus County	Nuclear Fuel Services
Oswego County	Nine Mile Point and Fitzpatrick NGS's
Wayne County	Ginna NGS
Albany County	(Background)

STATE OF WISCONSIN - DEPARTMENT OF HEALTH AND SOCIAL SERVICES

Location
Point Beach NGS
Kewaunee NGS
Green Bay Pumping Station, Rostock (background)

CANADA DEPARTMENT OF NATIONAL HEALTH AND WELFARE

National Fallout Network	Reactor Monitoring Program
Thunder Bay	Bruce NGS
Sault Ste. Marie	Pickering NGS
Windsor	
Toronto	
Hamilton	

Precipitation samples are presently being collected at more than 25 stations, three of which are in the Great Lakes basin. Samples are composited monthly and analyzed for ^{3}H, gross β, and γ-activity. Plutonium and uranium analyses are also performed for the above noted isotopes on selected precipitation samples.

The data from the ERAMS air monitoring program are tabulated in "Environmental Radiation Data", which is published quarterly. Average gross β values for air particulate samples collected in the Great Lakes basin during 1981 and the first half of 1982 are given in Table 48. The average concentration for 1981 was 0.08 pCi/m^3, and the average concentration for the first half of 1982 was 0.02 pCi/m^3.

The average gross β values reported from the ERAMS program are remarkably consistent across the United States for any given month. Gross β values showed an increase, starting with samples collected in November 1980; values reached a peak in April-May 1981 at all Great Lakes stations, and declined thereafter to values at or near the analytical detection limit of 0.01 pCi/m^3. The maximum average gross β value reported at a Great Lakes station during this period was 0.21 pCi/m^3.

NEW YORK (37, 76)

The New York Department of Health collects air particulate samples at 13 locations around the state in the vicinity of nuclear facilities. Three of these locations are in the Great Lakes basin (Table 47). Air particulate and fallout samples are also collected at one location (Albany County) not affected by a nuclear installation. This station provides a measure of natural background radioactivity plus any worldwide buildup from the use of nuclear energy and from atmospheric testing of nuclear weapons.

Atmospheric particulate samples are collected on filters which are changed weekly. The filters are subsequently analysed for gross β. Quarterly composites of the filters are also analyzed for specific isotopes, including ^{137}Cs, ^{134}Cs, ^{106}Ru, ^{95}Zr-Nb, ^{90}Sr, and ^{7}Be. Air samples collected on charcoal cartridges are analyzed weekly for ^{131}I. Results are published quarterly and summarized in an annual report.

The State of New York made the following observations from their 1981 and 1982 atmospheric particulate data (see Table 49). The overall average gross β level for atmospheric particulate samples collected during 1981 in the vicinity of nuclear facilities and at the background station was 0.071 pCi/m^3. This was greater than the 1980 average of 0.015 pCi/m^3, but typical of recent years. In 1981, the Albany background samples averaged 0.068 pCi/m^3. In 1982, the overall average gross β level was 0.014 pCi/m^3, in close agreement with the 1980 average.

Air particulate samples were collected during 1981 at one station in the predominant downwind direction of the former Nuclear Fuel Services site. The gross β level in all samples was similar to other areas of the state and indicate no influence from the plant. The results from analyses for specific isotopes also indicate no influence.

TABLE 48

ATMOSPHERIC RADIOACTIVITY CONCENTRATIONS
ERAMS - 1981 AND 1982

STATION LOCATION[a]	Gross β (pCi/m^3)[b]	
	1981	1982[d]
Chicago, Illinois	0.07	0.02
Lansing, Michigan	0.07	0.03
Niagara Falls, New York	0.08	0.02
Syracuse, New York	-	0.02
Toledo, Ohio	0.08	0.02
Madison, Wisconsin	0.07	0.02
Average[c]	0.08	0.02

a. Only those stations in the Great Lakes basin.
b. Analytical detection limit = 0.01 pCi/m^3.
c. For Great Lakes stations.
d. January-June 1982 only.

TABLE 49

ATMOSPHERIC RADIOACTIVITY CONCENTRATIONS
NEW YORK - 1981 AND 1982

STATION LOCATION[a]	Gross β (pCi/m^3)	
	1981	1982
Cattaraugus County	0.073	0.015
Oswego County	0.065	0.014
Wayne County	0.071	0.014
Albany (background)	0.068	0.015
Average[b]	0.071	0.014

a. Only those stations in the Great Lakes basin.
b. For all locations in New York.

Since the facility no longer reprocesses spent fuel, plutonium sampling has been discontinued.

In general, samples collected from the air station near the Nine Mile Point and the Fitzpatrick nuclear generating plants and from the air station near the Ginna plant showed levels consistent with other current ambient statewide levels in both 1981 and 1982.

WISCONSIN (44)

The Wisconsin Department of Health and Social Services collects atmospheric samples at three locations in the Great Lakes basin (Table 47).

Atmospheric particulate samples are collected on filters which are changed weekly. These filters are subsequently analyzed for gross ß. The weekly filters are also combined and analyzed monthly for γ-emitting isotopes, including ^{137}Cs, ^{106}Ru, ^{95}Zn-Nb, ^{7}Be, and ^{144}Ce. A charcoal cartridge is run in tandem with the particulate sampler and is also changed weekly. The cartridge is analyzed for ^{131}I. Results are available from the Division of Health of the Department of Health and Social Services.

Based on the State of Wisconsin's analyses, the average gross ß level for the three Great Lakes stations was 0.058 pCi/m^3 in 1981 and 0.013 pCi/m^3 in 1982 (Table 50).

CANADA DEPARTMENT OF NATIONAL HEALTH AND WELFARE (16, 24, 25, 39)

The Environmental Radiation Hazards Division, Radiation Protection Bureau, Department of National Health and Welfare, operates a national fallout network across Canada, with five stations located in the Great Lakes basin (Table 47). Analyses are performed to determine gross ß activity in surface air particulate samples and in precipitation. Air filters are collected and analyzed weekly for gross ß activity in air particulates. Monthly precipitation samples are composited quarterly for analysis.

Samples are also collected as part of the Reactor Monitoring Program, at stations located in the vicinity of the Bruce and the Pickering nuclear generating stations. Samples are analyzed for ^{3}H, the principal radionuclide released from the CANDU reactor.

The results of analyses of samples collected in 1981 and 1982 at stations in the national fallout network and the Reactor Monitoring Program located in the Great Lakes basin are given in Table 51. The average gross ß levels were 0.082 pCi/m^3 for 1981 and 0.021 pCi/m^3 for 1982.

SIGNIFICANCE OF REPORTED RESULTS

The annual average ambient gross ß levels reported by the U.S. Environmental Protection Agency, Wisconsin, New York, and the Canada Department of National Health and Welfare, and presented above, are consistent with each other. The data all show an increase in the average annual gross ß levels reported in 1981 over levels reported for 1980 and 1982. In addition, the U.S. Environmental Protection Agency's ERAMS program and National Health

TABLE 50

ATMOSPHERIC RADIOACTIVITY CONCENTRATIONS
WISCONSIN - 1981 AND 1982

STATION LOCATION	Gross ß (pCi/m^3)	
	1981	1982
Kewaunee	0.079	0.015
Point Beach	0.023	0.010
Rostock	0.071	0.015
Average	0.058	0.013

TABLE 51

ATMOSPHERIC RADIOACTIVITY CONCENTRATIONS
DNHW - 1981 and 1982

NATIONAL FALLOUT NETWORK	Gross ß (pCi/m^3)	
	1981	1982
Thunder Bay	0.068	0.022
Sault St. Marie	0.070	0.016
Windsor	0.086	0.022
Toronto	0.084	0.016
Hamilton	0.103	0.027
Average	0.082	0.021
REACTOR MONITORING PROGRAM	^3H (pCi/m^3)	
	1981	1982
Bruce NGS	51.3	32.4
Pickering NGS	40.5	51.3

and Welfare's national fallout network reported that peak gross ß values for stations located in the Great Lakes basin occurred in the spring of 1981. This increase and subsequent peak were due to fallout of residual radioactivity from the atmospheric weapons test conducted in October 1980.

For 1980, New York reported an annual average gross ß level of 0.015 pCi/m^3. For 1981, New York, Wisconsin, U.S. EPA, and National Health and Welfare reported average levels of 0.071, 0.058, 0.08, and 0.082 pCi/m^3, respectively. For 1982, Wisconsin, New York, U.S. EPA, and National Health and Welfare reported average levels of 0.013, 0.014, 0.02 and 0.021 pCi/m^3, respectively. The maximum reported gross ß level from the ERAMS program for a station in the Great Lakes basin was 0.21 pCi/m^3, in both April and May 1981; from the National Health and Welfare program, the maximum level was 0.27 pCi/m^3 in April 1981 (see below).

The data presented above would indicate no measurable levels of gross ß in the atmosphere resulting from the operation of nuclear generating stations in the Great Lakes basin.

SPECIAL MONITORING PROGRAMS

The Canada Department of National Health and Welfare undertook special studies in the vicinity of the Pickering nuclear generating station and the Nanticoke coal-fired generating station, the Eldorado Resources refinery at Port Hope, and as a result of the atmospheric weapons test conducted on Oct. 16, 1980 by the Peoples Republic of China. The results of the first study are described in Chapter 4 of this report, and the last two are discussed below.

ATMOSPHERIC WEAPONS TEST (16, 25)

The leading edge of the October 16, 1980 weapons test reached the west coast of Canada on October 19 at an altitude of 9,000 to 15,000 metres. Nationwide daily monitoring of surface air for gross ß activity was carried out from October 17 to November 14. Air filters were changed daily.

Fresh fallout radioactivity was first observed on air filters collected at ground level on October 28. The radionuclides identified in both the air samples as well as in precipitation samples were ^{95}Zr, ^{95}Nb, ^{99}Mo, ^{103}Ru, ^{131}I, ^{140}La, ^{141}Ce, ^{237}U, and ^{239}Np. Gross ß levels in air particulates during this period reached levels 3 to 10 times higher than those measured during the same period in 1979. The highest value recorded (in Calgary) was, however, less than 0.001 of the maximum permissible level.

Gross ß levels in air continued to be strongly influenced by the test for some time after the event; this finding is corroborated by data provided from the ERAMS program. In April 1981, one of National Health and Welfare's stations in southern Ontario reported a maximum air concentration of 0.27 pCi/m^3, a factor of ten higher than concentrations measured in April 1980. Results also indicated that the weapons test had a greater influence on air than on precipitation.

URANIUM EMISSIONS AT PORT HOPE (16)

As a result of a faulty baghouse filter at the Eldorado Nuclear refinery at Port Hope, from December 1980 to April 1981 the reported level of uranium in dustfall was 100 times the normal value, and the estimated air concentration exceeded 1 $\mu g/m^3$ (1,000 ng/m^3).

Subsequent to correction of the problem, the Department of National Health and Welfare conducted a one-year study of uranium concentrations in air and precipitation, in order to confirm that uranium concentrations had decreased, to determine the chronic levels of uranium exposure to people in the town of Port Hope, and to evaluate the health significance of the enhanced uranium emissions.

The Department estimated that the critical receptor would have received a committed lung dose of 20 mSv (2,000 mrem), or an effective whole-body dose of 3mSv (300 mrem), as a result of the enhanced emissions during the period. Further, if the enhanced levels had persisted for a whole year, the effective dose commitment would have exceeded the ICRP annual limit of 5mSv (500 mrem) for members of the public (28).

Airborne particulate matter was collected at five monitoring stations in the Port Hope area. The size distribution of the particles was determined, since this is critical for estimation of the dose; lung deposition increases as particle size decreases.

Between July and December 1981, the average concentration of uranium varied between 5 and 20 ng/m^3, compared to the estimated concentration of 1,000 ng/m^3 prior to correction of the problem, and compared to normal background levels of 0.1 ng/m^3 for rural locations in southern Ontario. The highest observed value during a one-week period was 160 ng/m^3, at a site just west of the refinery.

Particle-size measurements showed that the mass median diameter of uranium-bearing particles was not significantly larger than that of normal airborne particles. Using the standard ICRP lung model, the highest annual dose commitment to the lung was 3mSv (300 mrem) at the one above-mentioned site for the one-week period of sample collection. Dose commitments at the other sites were an order of magnitude lower.

8. Remedial and Safety Measures

In its July 1979 report, the Radioactivity Subcommittee provided a detailed description of the Canadian and the United States nuclear fuel cycles, including the status of, and options for, waste management. The Subcommittee also described the expected impact of the various components of the nuclear fuel cycle under both normal and abnormal operations, plus the impact of existing facilities in the Great Lakes basin.

The purposes of this chapter are to:

1. Provide an update regarding specific remedial measures to reduce the impact of specific nuclear fuel cycle activities in the Great Lakes basin.

2. Describe progress to develop repositories for the permanent disposal of high-level radioactive waste.

3. Describe measures implemented specifically to prevent unplanned releases of radioactivity to the ecosystem.

SPECIFIC REMEDIAL MEASURES

This section describes specific remedial measures designed to mitigate the impact of:

1. Mine tailings in the Serpent River basin.

2. Refinery wastes in the Port Hope area.

3. Other low-level wastes in Canada.

4. High-level reprocessing wastes at the Western New York Nuclear Service Center.

MINE TAILINGS IN THE SERPENT RIVER BASIN

The sources of radioactivity to the Serpent River are natural inputs from the bedrock and surface water leaching of radium and thorium from uranium mine tailings at both active and abandoned sites in the Elliot Lake area. Remedial measures implemented at active mine sites have resulted in the precipitation of much of the radioactivity into settling ponds. The concentration of radium reported at the mouth of the Serpent River over the past several years is only about 20% of concentrations observed during the late-1960's (Table 21).

Several studies (2) have been conducted at abandoned sites with the general objectives of establishing the geochemical dynamics and biological behaviour of these sites, quantifying their impact, and developing measures to mitigate releases of radioactivity and, consequently, their impact. Several remedial works have been implemented in the Elliot Lake area.

The old tailings sites at Strike and Crotch Lake are now under active control by the Panel and Stanleigh operating licenses. At the Stanrock site, improvements have been made to stabilize the dam and surface erosion. A water treatment plant is now in place, and seepages from the west side are contained and pumped to the treatment plant. At the Nordic and Pronto sites, water treatment is in place and a vegetative cover of the tailings is now well established.

The Atomic Energy Control Board has imposed license conditions on Denison Mines Ltd. to submit decommissioning plans for the Williams Lake and Stanrock tailings areas, within one year of their being given Board criteria and guidelines.

Denison Mines Ltd. and Rio Algom Ltd. are pursuing a joint sulphuric acid plant in Elliot Lake, where pyrite would be extracted from tailings. This would minimize acid leaching after decommissioning.

REFINERY WASTES IN THE PORT HOPE AREA

Several initiatives are underway in the Port Hope area concerning the management of radioactive refinery wastes (2, 87).

Eldorado Resources Ltd. is studying alternative options for the disposal of its refinery wastes, which are presently stored in near-surface, in-ground burial facilities near Welcome and Port Granby, Ontario. It is intended that the preferred option and site will accommodate the waste and contaminated soil inventories from these two facilities.

Eldorado will continue to bury wastes at the present facility at Port Granby until 1986. At that time, the company intends to begin construction of the new disposal facility and to begin decommissioning the two burial sites presently in use. The company intends to complete the activities by 1990. During the decommissioning, the regulatory objectives for releases to Lake Ontario will be in compliance with the present effluent discharge limits that are specified in the operating licenses.

Eldorado is also developing a recycling program, the company intends to have reached the point that, by 1986, all on-going wastes produced at the Port Hope refinery will either be recycled, or the small amount which cannot be recycled will be stored in drums at the Port Hope facility.

In the Town of Port Hope itself, the federal Low-Level Waste Management Office is investigating alternative option for the excavation of historic wastes, containing radium and uranium, from publicly accessible areas and their consolidation and disposal in one location. Examination of options and implementation of the preferred option is likely to span several years. The impact of these activities on the water quality of Lake Ontario is expected to be negligible.

OTHER LOW-LEVEL WASTES IN CANADA

Ontario Hydro is examining concepts for the disposal of low-level wastes that are presently stored at their site at Tiverton, Ontario (2). Disposal concepts involve engineered emplacement in various geologic media. No schedule has been publicly announced.

WEST VALLEY DEMONSTRATION PROJECT

The former Nuclear Fuel Services (NFS) fuel reprocessing facility, at West Valley, New York reprocessed fuel between 1966 and November 1971 and was closed in 1972. The facility also received solid radioactive waste for burial in trenches from 1963 until March 1975 (30, 37).

Water pumped from the trenches at the low-level waste burial site are treated at the low-level waste treatment facility and released in a controlled manner to the surface water drainage. Surface water runoff from the site drains into Buttermilk Creek, which drains into Cattaraugus Creek which, in turn, discharges into Lake Erie.

Although elevated, the levels of radioactivity, as measured at Springville Dam and reported as gross α, gross β, ^{90}Sr, and ^{3}H, are all within the U.S. Nuclear Regulatory Commission's technical specifications and also meet the Environmental Protection Agency's drinking water standards (see Table 23).

A much more serious issue is how to treat and dispose of the approximately 600,000 gallons of high-level radioactive wastes which are stored underground at the site. The wastes are composed of a sludge phase and an aqueous supernatent solution.

The West Valley Demonstration Project Act (P.L. 96-368), signed October 1, 1980, directed the U.S. Department of Energy to carry out a demonstration project to:

1. Solidify, in a form suitable for transportation and disposal, the high-level wastes, using vitrification or, if more suitable, another effective technology.

2. Develop containers suitable for the permanent disposal of this waste.

3. Transport the waste to an appropriate federal repository for permanent disposal.

4. Dispose of the low-level and the transuranic waste produced by solidification of the high-level waste.

5. Decontaminate and decommission the tanks and facilities in which the waste was stored, the facilities used in the solidification procedure, plus any other materials and equipment used in the project.

The Department of Energy prepared, in 1981, in compliance with the National Environmental Policy Act, a draft environmental impact statement (EIS) and subsequently, in June 1982, a final EIS entitled, "Long-Term Management of Liquid High Level Radioactive Wastes Stored at the Western New York Nuclear Service Center West Valley" (52).

The EIS assessed and compared environmental implications of four basic alternatives, with options within these alternatives, for the long-term management of the wastes:

1. On-site processing to a terminal waste form for shipment and disposal in a U.S. federal repository.

2. On-site conversion to a solidified interim form for shipment to a U.S. federal waste facility, later processing to a terminal form, and shipment and subsequent disposal in a U.S. federal repository.

3. Mixing the liquid wastes with cement and other additives, pouring it back into the existing tanks, and leaving on site.

4. No action, i.e. continued storage of the wastes in liquid form in the underground tanks, either indefinitely with the wastes periodically transferred to new storage tanks or, after 10 years, reconsidering solidification alternatives.

On September 9, 1982, the Department of Energy issued (53) a Record of Decision "to construct and operate the facilities necessary to solidify the liquid high-level radioactive wastes . . . ." The components would "be separated into a concentrated high-level radioactive terminal waste form suitable for transportation and disposal in a Federal geologic repository and a low-level radioactive salt cake." Although none of the alternatives in the EIS was so environmentally superior that it could be identified as clearly preferable, this approach as selected since, of the four alternatives, it provides for isolation of the waste from the human environment and, therefore, offers the greatest protection for current and future generations from its potential hazards. Also, this alternative had minimum reliance on maintenance and surveillance.

Ongoing efforts will further refine the design, construction, and operational aspects of the project.

In June 1983, the Department of Energy announced selection of borosilicate glass as the waste form for the high-level waste. The selection was based on studies particular to the West Valley Project, as well as other existing environmental documentation. A report has been published which discusses the basis for selection (54).

Related discussions, such as final decontamination and decommissioning of solidification facilities, and the siting and design of the repository will be addressed in subsequent environmental analyses.

The solidified high-level waste would most likely be stored at the West Valley site until such time that a federal repository becomes available, in the late 1990's.

Disposition of low-level waste is another decision which will have to be made. There are two principal options:

1. Packaging and storage on site until transport to a regional low-level waste burial site can be effected.

2. Use of the U.S. NRC licensed burial area at West Valley.

Westinghouse Electric Corporation was selected in August 1981 by the Department of Energy as the prime contractor (government owned, contractor operated) for the West Valley Demonstration Project. Westinghouse formed the West Valley Nuclear Services Company, Inc. (WVNS). On February 25, 1982, WVNS and the Department of Energy formally assumed possession of the site from the state of New York, which had assumed ownership following withdrawal of the Nuclear Fuel Services Company.

WVNS, in cooperation with subcontractors and various state and federal government agencies, has undertaken numerous activities with regard to development of the solidification process, decontamination and decommissioning, site operations, environmental documentation, and construction and project management. Among the first major projects was selection of the solid form into which the liquid wastes will be converted and the process that will be used for the conversion; as noted above, borosilicate glass has been selected as the waste form. The next step will be the design and construction of the reprocessing facility. Actual solidification of the wastes is not expected to begin until near the end of the decade. Once begun, it will take about three years to solidify all the high-level wastes at the site.

Total expenditures for FY 1982 were $6.9 million. Planned expenditures for FY 1983 were $15.4 million. Anticipated expenditures for FY 1984 are $36.0 million. Detailed plans, schedules, and cost estimates for work beyond FY 1984 are under development.

A summary of FY 1982 accomplishments, FY 1983 objectives, and FY 1984 goals are contained in the FY 1982 annual report of the project (55).

HIGH-LEVEL RADIOACTIVE WASTE

CANADA (2)

In Canada, with regard to high-level waste management and disposal, a federal-Ontario agreement was renewed in August 1981 to pursue the development of a concept for disposing of nuclear fuel waste at depth in a hard, crystalline rock formation in the Canadian Shield. Atomic Energy of Canada Ltd. is conducting a number of geological research programs and projects associated with the safety assessment of a nuclear fuel waste disposal vault.

This generic research and development program is planned to be completed in 1990, with site selection commencing at some time thereafter. In the meantime, nuclear fuel wastes are stored in the form of intact spent fuel bundles in water filled pools at reactor sites.

Research and development has also continued on immobilization technologies for both irradiated fuel and on the wastes that would result from reprocessing the fuel.

Atomic Energy of Canada Ltd. has published a comprehensive bibliography of over 300 reports, plus another 300 technical records, which describe scientific and technical aspects of work in the Canadian Nuclear Fuel Waste Management Program (56). The Canadian Nuclear Society has also published the proceedings of an international conference on radioactive waste management, held in 1982 (57).

UNITED STATES

Nuclear fuel wastes are stored at reactor sites in the United States in a manner similar to that used in Canada. The plans are to keep the wastes on site until permanent disposal facilities are available. This may mean storage of the waste at a site after the operating license of the generating facility has expired or after a permanent shutdown has occurred. In addition, the storage capacity at some sites may have to be increased.

The Nuclear Waste Policy Act, passed by the U.S. Congress in 1982, gives the U.S. Department of Energy until 1987 to choose a site for the first U.S. repository, with tests using radioactive materials scheduled for 1990. The first repository is to be operational by 1998. The Department of Energy has started looking at nine sites in six states which may be suitable for the first repository (61).

In December 1982, the U.S. Environmental Protection Agency proposed environmental standards for the management and disposal of spent reactor fuel, high-level wastes derived from reprocessing spent fuel, and wastes containing long-lived transuranic radionuclides (58).

The proposed standards would limit the risks to both present and future generations and would adequately protect the public from harm caused by management and disposal activities related to these wastes. Subpart A addresses activities related to waste management and storage operations preparatory to disposal, and Subpart B addresses the long-term performance of disposal systems.

The standards for Subpart A would not permit radiation exposure to members of the public to substantially increase beyond that now accepted for normal operations of the uranium fuel cycle.

Subpart B, which deals with an unproven technology and with the need to extend public health protection far into the future, proposes containment requirements that place quantitative numerical limits on possible releases to the environment for 10,000 years after disposal. The requirements are not specific to any particular method of disposal, but do focus on mined geological repositories.

Because the uncertainties inherent in projecting disposal system performance for 10,000 years, Subpart B also contains seven qualitative criteria that are needed to develop appropriate confidence that the containment requirements will be met. The assurance requirements call for well designed, multiple-barrier disposal systems that do not rely on perpetual maintenance. Further, the disposal system should be located where disturbance by natural forces or human activities would be unlikely.

The U.S. Environmental Protection Agency has also published a technical report which presents the methodology used to assess the long-term population risks from projected releases of waste from a geologic repository (59).

In May 1983, the U.S. National Academy of Sciences published a report which confirmed that the technology for a permanent underground repository is feasible and ready for testing (60). However, additional detailed research at candidate sites is needed before a repository is actually built and put to work. Detailed research is also needed on how to package the wastes, the effects of groundwater, and how to seal the repository once it is filled. The report also questions the procedure followed by the U.S. Environmental Protection Agency to set safety criteria for the repository.

SAFETY PROGRAMS

In order to ensure that nuclear power reactors are constructed, maintained, and operated at a high level of integrity, and to improve the overall performance of the nuclear power industry as a whole, several initiatives have been undertaken in both the United States and Canada. Certain of these are briefly described below.

UNITED STATES

Six initiatives for the nuclear power industry in the United States are:

1. Unresolved Safety Issues (USI) Program by the U.S. Nuclear Regulatory Commission (NRC).
2. Three Mile Island (TMI) Action Plan, developed by the U.S. NRC.
3. Systematic Assessment of Licensee Performance (SALP) program by the U.S. NRC.
4. Systematic Evaluation Program (SEP) by the U.S. NRC.
5. Institute of Nuclear Power Operations (INPO), supported by the electric utility industry.
6. The U.S. NRC Enforcement Program.

Unresolved Safety Issue Program (79)

Section 210 of the Energy Reorganization Act of 1974, as amended, requires that the U.S. NRC report annually on programs to resolve items identified as Unresolved Safety Issues (USI's). Generic issues were initially identified in

1978 (80) and, subsequently, 22 of these issues were selected for specific consideration, because of their importance to public health and safety (81). As a result of the Three Mile Island accident, plus considerable additional operating experience, five additional USI's were identified in 1981 (82).

The procedures for the USI Program includes development of a proposed technical resolution by U.S. NRC staff. When the proposal is issued, public comment is solicited. These comments are considered in the final report. The agreed-upon technical resolution is then incorporated as appropriate into the U.S. NRC's regulations, Standard Review Plan, Regulatory Guides, or other official guidance. The final technical resolution is then applied to operating plants.

A summary of the status of USI's is published quarterly, and a progress report is presented in the annual report of the U.S. NRC. According to the 1982 annual report (83), final technical resolution has been achieved for 13 of the 27 USI's, and measures have been, or are in the process of being implemented. For the 14 remaining USI's, work is to be completed by October 1985.

Three Mile Island Action Plan (79)

The accident at the Three Mile Island - 2 reactor in Pennsylvania occurred in 1979. Numerous studies and investigations were subsequently conducted into the cause of the accident. These were conducted not only by the U.S. NRC but also by Congress, a presidential commission, and various state groups, individual utilities, and industrial organizations. As a result, a number of needed changes were identified in the regulatory requirements for nuclear power reactors, both those with an operating license and those under application for an operating license. In all, more than one thousand recommendations for corrective action were developed.

In late 1979, the U.S. NRC began development of the Three Mile Island Action Plan. The purpose of the Plan was to make regulatory and licensing functions more timely, and to improve safety measures. The above-noted recommendations served as a starting point for the Plan. The Plan itself consolidated and defined these recommendations into a set of discrete tasks that specified changes (or studies of possible future changes) in regulatory requirements and in the organization and procedures of the U.S. NRC. The Plan contained approximately 175 discrete short- and long-term actions, organized into five broad subject areas: operational safety; siting and design; emergency preparedness and radiation effects; regulatory practices and procedures; and U.S. NRC policy, organization, and management.

Each action was assigned a priority and schedule for implementation, based on the estimated resource requirements to accomplish each action, the significance of the safety issue involved, and the relative risk-reduction potential for a particular action. The Action Plan also catalogued decisions and actions taken by the U.S. NRC in the year following the accident. Details of the Plan have been published (84, 85), and the U.S. NRC prepares quarterly status reports in an Action Plan Tracking System.

The majority of the recommended actions have now been implemented or are in the process of implementation.

Systematic Assessment of Licensee Performance (1, 62)

The Systematic Assessment of Licensee Performance (SALP) program was initiated by the U.S. Nuclear Regulatory Commission on January 1, 1979 to assess licensee performance. The program applies to all power reactors with operating licenses or construction permits. The "goal of SALP is to improve performance of the industry as a whole and to give greater assurance to the public that nuclear power reactors are operated safely."

The objectives of SALP are:

1. To improve the U.S. NRC regulatory program in terms of resource allocation.

2. To improve licensee performance.

3. To collect information and observations on an annual basis and to evaluate licensee performance based on these observations.

Positive and negative attributes of licensee performance are considered. Emphasis is placed on understanding the reasons for a licensee's performance in important functional areas, and sharing this information with the licensee. Licensees are evaluated in the functional areas listed in Table 52. Evaluation criteria are listed in Table 53.

Reviews are conducted by the SALP Review Group, composed of representatives from the Office of Nuclear Regulation, the Office of Analysis and Evaluation of Operating Data, and the Office of Inspection and Enforcement. Reports are published annually; each covers an appraisal period of 12 months, plus a 6-month period for review and evaluation of collected information. Facilities are rated as above average, average, or below average.

It should be noted that "a rating of below average does not mean that a facility (is) unsafe or that its operations or construction should be stopped. The expected performance level for nuclear facilities is high. . . . A rating of below average means that a facility was not meeting the full measure of these high expectations and that, relative to (other) nuclear facilities (in the United States), the facility's performance was judged to be less desirable than most other facilities."

A summary of SALP findings, with regard to radiological control for nuclear generating stations in the Great Lakes basin, for 1982, is presented in Table 54. Since the findings during the appraisal and evaluation are discussed with the licensees, identified weaknesses are in various stages of correction. The SALP report does not reflect the status of such corrective actions, since these actions are dynamic. These actions are, however, reflected in the SALP report for the next review period.

Systematic Evaluation Program (79)

The Systematic Evaluation Program was initiated in 1977 by the U.S. Nuclear Regulator Commission. The basic purpose of the Program is to reconfirm the safety of older nuclear power plants in the United States. The review compares the as-built plant with current licensing criteria and

TABLE 52

SYSTEMATIC ASSESSMENT OF LICENSEE PERFORMANCE
FUNCTIONAL AREAS FOR MONITORING AND EVALUATION

OPERATING REACTORS	CONSTRUCTION PHASE REACTORS
(1) Plant operations	(1) Soils and foundation
(2) Radiological controls	(2) Containment and other safety-related structures
(a) radiation protection	(3) Piping systems and supports - includes welding, NDE and preservice inspection
(b) radioactive waste mgmt.	(4) Safety-related components - includes vessel, internals, pumps
(c) transportation	(5) Support systems - includes HVAC, radwaste, fire protection
(d) effluent control and monitoring	(6) Electrical power supply and distribution
(3) Maintenance	(7) Instrumentation and control systems
(4) Surveillance - includes inservice and preoperational testing	(8) Licensing activities
(5) Fire protection	(9) Others (as needed)
(6) Emergency preparedness	
(7) Security and Safeguards	
(8) Refueling - includes initial fuel loading	
(9) Licensing activities	
(10) Others (as needed)	

TABLE 53

SYSTEMATIC ASSESSMENT OF LICENSEE PERFORMANCE
EVALUATION CRITERIA

(1) Management involvement in assuring quality
(2) Approach to resolution of technical issues from safety standpoint
(3) Responsiveness to U.S. Nuclear Regulatory Commission initiatives
(4) Enforcement history
(5) Reporting and analysis of reportable events
(6) Staffing (including management)
(7) Training effectiveness and qualification

TABLE 54

SUMMARY OF SALP FINDINGS FOR 1982
RADIOLOGICAL CONTROL

FACILITY	FINDINGS - RADIOLOGICAL CONTROL
Big Rock Point	Some weakness
D.C. Cook	Satisfactory performance
Davis-Besse	High level performance
Fitzpatrick	Some weakness
Ginna	Satisfactory performance
Kewaunee	High level performance
Nine Mile Point 2	Some weakness
Palisades	Some weakness
Point Beach	High level performance
Zion	Some weakness

determines where there is a need for change. Significant areas of safety examined include systems required for safe shutdown of a plant, and the ability of the plant to cope with such potential natural events as earthquakes, floods, and tornadoes.

The Program provides:

1. An assessment of the significance of differences between current technical positions on safety issues and those that existed when the plant was licensed.

2. A basis for deciding how these differences should be resolved in an integrated plant review.

3. A documented evaluation of plant safety.

The original SEP objectives were:

1. The Program should establish documentation that shows how the criteria for each operating plant reviewed compare with current criteria on significant safety issues, and should provide a rationale for acceptable departures from these criteria.

2. The Program should provide the capability to make integrated and balanced decisions with respect to any required backfitting.

3. The Program should be structured for early identification and resolution of any significant deficiencies.

4. The Program should assess the safety adequacy of the design and operation of currently licensed nuclear power plants.

5. The Program should efficiently use available resources and summarize requirements for additonal resources by the U.S. NRC or by the industry.

The Program objectives were later interpreted to ensure that the SEP also provide safety assessments adequate for the conversion of provisional operating licenses to full-term operating licenses.

In Phase I of the Program, the guidelines, techniques, and review areas to be evaluated were developed. A total of 137 issues were identified for review at each plant.

In Phase II, eleven of the oldest power plants in the United States are being evaluated, two of which - Palisades and Ginna - are in the Great Lakes basin. The systematic evaluation of these plants has improved overall plant safety and has provided documentation of the extent to which the plants conform to current licensing requirements.

Based on analysis of Phase II, the U.S. NRC is considering a Phase III for 11 additional operating reactors, but for a reduced number of topics.

Palisades Nuclear Generating Station (63)

In April 1982, the U.S. NRC's Advisory Committee on Reactor Safeguards (ACRS) reviewed the results of the safety review and the Integrated Plant Safety Assessment for the Palisades facility. The U.S. NRC staff issued a final safety assessment in November 1982.

Of the 137 topics to be addressed by the SEP, 23 were not applicable to the Palisades facility. In order to avoid duplication and to ensure the timely completion of the review, an additional 24 topics were not addressed; these topics were identical with matters being reviewed by the U.S. NRC in connection with the resolution of Unresolved Safety Issues or TMI Action Plan requirements.

Of the 90 topics reviewed, 57 met current U.S. NRC criteria or were acceptable on other defined bases. As a result of modifications by Consumers Power Company, which operates the facility, two additional topics met the criteria.

The Palisades facility did not meet current criteria for all or part of the remaining 31 topics. These topics were addressed by the Integrated Assessment and have been resolved in various ways:

1. Addition or modification of equipment.

2. Development or modification of procedures or technical specifications.

3. No backfit was required.

At the time of the ACRS's review of the report, the Integrated Assessment had not been completed for 9 topics, primarily because information was still forthcoming from Consumers Power Company. The information consisted of calculations, evaluations, and various other submittals which were required by the U.S. NRC as bases for assessments and decisions. The resolution of these topics will be addressed in a supplemental report.

The findings of the review and assessment for the Palisades facility are documented in the U.S. NRC report, "Integrated Plant Safety Assessment, Systematic Evaluation Program - Palisades Plant" and its Supplements (64).

Ginna Nuclear Generating Station (65)

In May and in July 1982, the ACRS reviewed the results of the SEP for the Ginna facility. The U.S. NRC staff issued a final safety assessment in February 1983.

Of the 137 topics to be addressed by the SEP, 21 were not applicable to the Ginna facility; 24 additional topics were deleted from review, because they were being addressed generically under either the Unresolved Safety Issues Program or the TMI Action Plan.

Of the 92 topics reviewed, 58 met current U.S. NRC criteria or were acceptable on other defined bases. As a result of modifications made or committed to by the Rochester Gas and Electric Corporation, which operates the facility, seven additional topics were subsequently added to the acceptable category.

The Ginna facility did not meet current criteria for all or part of the remaining 27 topics. These topics were addressed by the Integrated Assessment and have been resolved to various degrees in various ways:

1. Addition or modification of structures or equipment.

2. Development or modification or procedures or technical specifications.

3. Refined engineering analysis or continuation of ongoing evaluation.

4. No backfit was required.

At the time of the ACRS's review of the report, the Integrated Assessment had not been completed for portions of 7 topics, primarily because of information that was still forthcoming from Rochester Gas and Electric. The information consisted of results of studies, calculations, and evaluations which were required by the U.S. NRC for its assessments and decisions. These topics will be addressed in a supplemental report.

Three areas requiring resolution between Rochester Gas and Electric and the U.S. NRC are:

1. Groundwater level and the associated hydrostatic pressure which structures below grade must withstand. The plant was designed, assuming a groundwater elevation of 250 feet; the groundwater is presently near this elevation. Since there has been no program to demonstrate that the level does not exceed 250 feet during periods of prolonged precipitation, the U.S. NRC staff contends that the effects of groundwater should be evaluated at an assumed elevation of the surface of the ground, i.e. approximately 270 feet.

2. Flooding of the site by Deer Creek, a small stream which flows into Lake Ontario in the vicinity of the plant. Flooding from Lake Ontario, but not Deer Creek, was considered when the plant was originally licensed.

3. Several containment isolation valves which do not satisfy the requirements of the relevant design criterion.

The findings of the review and assessment for the Ginna facility are documented in the U.S. NRC report, "Integrated Plant Safety Assessment, Systematic Evaluation Program - R.E. Ginna Nuclear Power Plant"(66). A supplement will be issued to address the status of all TMI and Unresolved Safety Issue tasks applicable to the Ginna facility.

Institute of Nuclear Power Operations (62, 79)

The Institute of Nuclear Power Operations (INPO) was established in 1979 to promote safety and reliability in the construction and operation of nuclear power plants. It was self-initiated by the nuclear power industry in response to the issues and problems revealed in the aftermath of the Three Mile Island accident.

INPO's approach is performance oriented. Overall maintenance and technical support are studied through on-site visits. INPO prepares a report for the utility company, identifying areas which need strengthening or improvement. INPO's major programs and activities are:

1. Evaluation programs

2. Development of documents - criteria, guidelines, and good practices

3. Training accreditation

4. Analysis of events

5. Assistance to members

6. Information exhange.

Inspections have been made for several nuclear generating facilities in the United States portion of the Great Lakes basin.

Enforcement Program (79)

The purpose of the U.S. NCR's enforcement program is to protect public health and safety. The program ensures that licensees comply with regulatory requirements. The U.S. NRC policy calls for three types of enforcement action:

1. Notices of Violation are issued for all instances of non-compliance with U.S. NRC requirements.

2. Civil penalties are issued in case of significant or repetitive non-compliance or when a Notice of Violation has not been effective. Civil penalties may be imposed for particularly significant first-of-a-kind violations. Fines as high as $100,000 per violation may be imposed, with no ceiling on the total fine for any 30-day period.

3. Orders to cease and desist operations, or to suspend, modify, or revoke licenses are issued to cover extremely serious cases.

Enforcement action requires the licensee to correct the particular problem and to establish measures to preclude recurrence.

CANADA (2)

The Atomic Energy Control Board, in licensing nuclear reactors, issues licenses of relatively short term, i.e. only one to five years. The Board conducts a thorough review of the licensability of a facility before the license is renewed.

The Board also maintains a team of resident inspectors at the large nuclear power stations. One of their functions is to review on at least an annual, and usually a quarterly basis, the compliance of the facility with its license conditions, including the limits on doses to workers and the targets for the release of radioactive materials to the environment.

Because of the size and the structure of the nuclear power program in Canada, the Board has not found it necessary to organize a specific program to deal with unresolved safety issues. These issues do exist, but are generally dealt with on a project-specific basis.

As in the United States, the Atomic Energy Control Board investigated the implications of the Three Mile Island incident for nuclear power stations in Canada. The Board requested the utilities to address, investigate, or follow up on certain issues. The Board also undertook certain changes in its own operations and licensing guidelines.

Unlike the United States, the practices of the Atomic Energy Control Board and, indeed, the Canadian legal system, do not permit the assessment of fines through administrative processes. However, the Board can prosecute violations through the courts.

9. Summary

NUCLEAR FACILITIES IN THE GREAT LAKES BASIN

The 14 nuclear generating stations consisting of 23 reactors presently operating in the Great Lakes basin represent an installed electric generating capacity of 15.3 GW. Although plans for six additional nuclear generating stations have been cancelled and the construction schedules for other stations have been extended, the current construction program nonetheless calls for nuclear capacity to almost double by the mid-1990's.

In response to economic factors, uranium mining and milling operations in the basin have been reduced. The uranium oxide refinery at Port Hope is scheduled to be closed by the end of 1983. However, a new uranium oxide refinery has been completed and has begun production at Blind River, on the North Channel, and capacity at the uranium haxafluoride production facility at Port Hope, on Lake Ontario, is being tripled.

Releases of radioactivity from routine nuclear operations in the Great Lakes basin are generally well within the limitations set out in the facilities' operating licenses. Similarly, unplanned releases of radioactivity have not resulted in license conditions being exceeded.

OBJECTIVES, STANDARDS, AND CRITERIA

AGREEMENT OBJECTIVE AND CALCULATION OF DOSE

The Agreement objective is in terms of dose to man, resulting from the ingestion of lake water. The dose can be calculated from measured concentration data, using appropriate conversion factors for each radionuclide of interest. In 1977, the International Commission on Radiological Protection (ICRP) announced changes in the way in which the dose to a particular organ or tissue is related to dose to the whole body; this changed the factors used to convert from concentration to dose. However, the ICRP did not publish its refined dose calculations until a later date. Consequently, in 1978, the Board's Radioactivity Subcommittee developed and used interim dose conversion factors. The ICRP has now published its refined calculations, and the Board's Radioactivity Advisory Group has developed the new concentration-to-dose conversion factors, which are fully in conformance with the ICRP, for use in determining compliance with the Agreement objective.

JURISDICTIONAL LIMITATIONS

The limitations established by the Great Lakes jurisdictions for radionuclides in water are based on the recommendations of the ICRP. As the body of available scientific data has increased, changes have taken place in the ICRP recommendations and, consequently, in the jurisdictional limitations.

In 1978, the Canada Department of National Health and Welfare published revised guidelines for specific radionuclides in water; the present limitations are more stringent than the previous values. In 1982, the Ontario Ministry of the Environment revised the provincial water quality objectives for radionuclides. The present limitations established by National Health and Welfare and by the Province are the same.

ASSESSMENT OF GREAT LAKES RADIOLOGICAL QUALITY

The Great Lakes International Surveillance Plan calls for surveillance and monitoring of radioactivity in the Great Lakes basin. These programs help meet the requirements of Annex 11 of the 1978 Agreement, including compliance with the specific Agreement objective for radioactivity, given in Annex 1.

DOSE TO MAN

Using available jurisdictional monitoring data in conjunction with the conversion factors described above, the annual doses (in millirems) resulting from the ingestion of lake water during 1981 and 1982 were:

LAKE	1981	1982
Superior	0.05	0.05
Michigan	0.07	-
Huron	0.09	0.09
Erie	0.08	0.08
Ontario	0.09	0.10

These values are all well below the Agreement objective of 1 millirem. ^{90}Sr contributes 80-90% of the total dose; the major source of this radionuclide is fallout from nuclear weapons testing.

DEGRADED AREAS

Radiological quality continues to be degraded in two areas within the Great Lakes basin: the Serpent River area and Port Hope Harbour.

In the Serpent River area, ^{226}Ra also contributes significantly to the total dose. Values calculated for 1981 and 1982 were 1.42 and 1.30 millirem, respectively. The source of ^{226}Ra is mining and milling upstream in the river basin.

The Agreement objective calls for investigation of sources and corrective action if releases are not as low as reasonably achievable. Numerous remedial measures have been undertaken in the Serpent River basin over the past two decades. As a result, the concentration of ^{226}Ra in the river has decreased almost ten-fold since 1966.

A materials balance for 1981 indicates that releases of dissolved ^{226}Ra from controlled sites in the Serpent River basin contributes only about 20% of the total loading from the river to the North Channel. Other sources are natural inputs as a result of weathering, releases from abandoned or closed facilities, and dissolution of ^{226}Ra contained in solids which are presently or which have previously been discharged as a result of mining operations.

Additional remedial measures are being considered, especially for abandoned or closed facilities.

The concentration of uranium inside Port Hope Harbour in 1981 and 1982 was generally above the maximum acceptable concentration of 20 µg/L established by the Canada Department of National Health and Welfare for a drinking water supply. Water outside the harbour is occasionally above this limiting value. The average concentration of uranium in treated drinking water at Port Hope in 1981 and 1982 was about 1.4 µg/L, compared with National Health and Welfare's objective of 1 µg/L. These findings are consistent with results reported for previous years.

The levels of gross α and gross ß inside Port Hope Harbour during 1981 and 1982 were frequently greater than the limitations established by the Canada Department of National Health and Welfare and by the Province of Ontario. Excursions are also occasionally reported outside the harbour. These findings are consistent with results reported for previous years.

COMPARISON AMONG THE LAKES AND TRENDS

Available surveillance and monitoring data indicate that the open waters of each of the Great Lakes are well mixed; however, there may be some variability between the nearshore and the open waters.

Available information also indicates that, by the early 1970's, radionuclide concentrations had decreased markedly from high levels recorded in the mid-1960's. This drop was attributable to reduced testing of nuclear weapons in the atmosphere. The levels of some radionuclides in the waters of the Great Lakes continue to decrease but, for other radionuclides, no downward trend is apparent. Also, there are variations among the lakes; for example, the concentration of ^{137}Cs is highest in Lake Superior and lowest in Lake Erie, probably because of the low flux of sedimenting particles in the former and the high flux in the latter.

ATMOSPHERIC MONITORING PROGRAMS

The results of routine atmospheric monitoring programs conducted in the Great Lakes basin indicate no measurable levels of gross ß radioactivity attributable to nuclear generating stations in the Great Lakes basin. However, the data do show an increase in the average annual level of gross ß for 1981 over average levels reported in 1980 and 1982, with peak values recorded in the spring of 1981. This was the result of fallout of residual radioactivity from an atmospheric nuclear weapons test conducted in October 1980.

The average level of uranium in dustfall in the Port Hope area during the latter half of 1981 was approximately 100 times higher than background levels recorded for rural locations in southern Ontario. The source was emissions from the uranium refinery at Port Hope. However, these atmospheric levels were approximately 100 times less than those recorded in late 1980 and early 1981, prior to correction of a faulty filter at the refinery.

RADIOACTIVITY FROM COAL FIRED AND NUCLEAR ELECTRIC GENERATING PLANTS

The Canada Department of National Health and Welfare conducted a study to compare the levels of radioactivity released from the combustion of coal at a coal-fired electric generating station with routine emissions from a nuclear generating station. The study found that radionuclide emissions from both facilities were negligible, especially when compared with levels of radioactivity already present from natural and other anthropogenic sources.

REMEDIAL AND PREVENTATIVE MEASURES

In Canada, specific remedial measures have been implemented, and others are under consideration, to reduce releases of radioactivity from mines and mills in the Serpent River basin. Eldorado Resources Ltd. is studying options for the disposal of wastes from its Port Hope refinery; these wastes are presently buried near Welcome and Port Granby. Eldorado is also developing a program which, it is intended, will result in the recycling of all wastes produced at the Port Hope refinery after 1986. Ontario Hydro is examining alternatives for the disposal of low-level wastes presently stored at Tiverton, Ontario.

In the United States, the West Valley Demonstration Project Act of 1980 directs the solidification and disposal of the high-level wastes presently stored at West Valley, New York. The project will require more than ten years.

Both Canada and the United States continue to conduct investigations and studies preparatory to the selection of sites, and the construction of repositories for the in-ground geologic disposal of high-level radioactive waste. The schedules in both countries extend beyond the end of this century.

Both nations have also undertaken initiatives to ensure that nuclear power reactors are constructed, maintained, and operated at a high level of integrity, and to improve the overall performance of the nuclear power industry as a whole.

References

1. U.S. data and information provided by L. K. Cohen, U.S. Nuclear Regulatory Commission, Washington, D.C., May 19, 1983.

2. Canadian data and information provided by R. M. Chatterjee, Atomic Energy Control Board, Ottawa, Ontario, June 15, 1983.

3. "1981 Report on Great Lakes Water Quality". Appendix - Great Lakes Surveillance. Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario, November 1981.

4. Energy Analects, November 19, 1982, p. 5.

5. Press release, No. I-83-94, from U.S. Nuclear Regulatory Commission, King of Prussia, Pennsylvania, July 26, 1983.

6. Atomic Energy Clearing House, Vol. 28, No. 5, February 1, 1982, p. 38.

7. Atomic Energy Clearing House, Vol. 28, No. 6, February 8, 1982, p. 38.

8. Science, Vol. 216, March 5, 1982, p. 1215.

9. Science, Vol. 216, April 30, 1982.

10. Chemical and Engineering News, February 1, 1982, p. 5.

11. Eco/Log Week, February 5, 1982, p. 4.

12. U.S. Nuclear Regulatory Commission, Washington, D.C., April 1982. Report No. NUREG-0909.

13. Personal communication on May 25, 1981 from R. M. Chatterjee, Atomic Energy Control Board, Ottawa, to M. P. Bratzel, Jr., International Joint Commission, Windsor.

14. Eco/Log Week, Vol. 9, No. 44, November 13, 1981, page 1.

15. Eco/Log Week, October 23, 1981, p. 6.

16. "Environmental Radioactivity in Canada, 1981," Radiological Monitoring, Annual Report, Health Protection Branch, Environmental Health Directorate, Department of National Health and Welfare, Ottawa.

17. Personal communication on May 4, 1983 from R. M. Chatterjee, Atomic Energy Control Board, Ottawa, to M. P. Bratzel, Jr., International Joint Commission, Windsor.

18. Eco/Log Week, February 12, 1982, p. 4.

19. Personal communication on December 24, 1982 from R. M. Chatterjee, Atomic Energy Control Board, Ottawa, to W. R. Drynan, International Joint Commission, Windsor.

20. Personal communication on January 17, 1983 from R. M. Chatterjee, Atomic Energy Control Board, Ottawa, to M. P. Bratzel, Jr., International Joint Commission, Windsor.

21. Eco/Log Week, February 11, 1983, p. 6.

22. McBride, J. P., R. E. More, J. P. Witherspoon, and R. E. Blanco, "Radiological Impact of Airborne Effluents of Coal and Nuclear Plants," Science, Vol. 202, 1978, pp. 1045-1050.

23. Styron, C. E., V. R. Casella, B. M. Farmer, L. C. Hopkins, P. H. Jenkins, C. A. Phillips, and B. Robinson, "Assessment of the Radiological Impact of Coal Utilization," Monsanto Research Corporation, 1979. Report No. MLM-2514.

24. "Environmental Radioactivity in Canada, July - December 1979," Radiological Monitoring, Semi-Annual Report, Health Protection Branch, Environmental Health Directorate, Department of National Health and Welfare, Ottawa, October 1980. Report No. 82-EHD-76.

25. "Environmental Radioactivity in Canada, 1980," Radiological Monitoring, Annual Report, Health Protection Branch, Environmental Health Directorate, Department of National Health and Welfare, Ottawa. Report No. 82-EHD-90.

26. "Guidelines for Canadian Drinking Water Quality, 1978," Prepared by the Federal-Provincial Working Group on Drinking Water of the Federal-Provincial Advisory Committee on Environmental and Occupational Health. Published by authority of the Minister of National Health and Welfare. Available from Department of Supply and Services, Hull, Quebec. Catalogue No. H48-10/1978.

27. Fisenne, I. M., P. M. Perry, and H. W. Keller, "Wet and Dry Deposition of Ra-226, Pb-210 and Stable Lead in an Urban Environment," Environmental Quarterly, EML-371, Environmental Measurements Laboratory, U.S. Department of Energy, Washington, D.C., April 1980.

28. "Recommendations of the International Commission on Radiological Protection," ICRP Publication 26, Pergamon Press, Oxford, Annals of the ICRP, Vol. 1, No. 3, 1977.

29. "Great Lakes Water Quality, 1977," Appendix D, Annual Report of the Radioactivity Subcommittee. Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario, July 1978.

30. "Great Lakes Water Quality, 1978," Appendix D, Annual Report of the Radioactivity Subcommittee, Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario, July 1979.

31. "Limits for Intakes of Radionuclides by Workers," ICRP Publication 30, Part 1, Pergamon Press, Oxford, Annals of the ICRP, Vol. 2, No. 3/4, 1979.

32. Calculations performed by R. E. Sullivan, U.S. Environmental Protection Agency, Washington, D.C., and contained in personal communications dated June 23, and August 2, 1983 to M. P. Bratzel, Jr., International Joint Commission, Windsor, Ontario.

33. "Ontario Drinking Water Objectives", Ontario Ministry of the Environment, Toronto, Ontario, April 1983.

34. "Water Management. Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment," Ontario Ministry of the Environment, Toronto, November 1978.

35. "National Interim Primary Drinking Water Regulations," Office of Water Supply, U.S. Environmental Protection Agency, Washington, D.C. Report No. EPA-570/9-76-003.

36. "Great Lakes International Surveillance Plan," Prepared by the Surveillance Subcommittee of the Great Lakes Water Quality Board, International Joint Commission, Windsor.

37. "Annual Report of Environmental Radiation in New York State, 1981," New York State Department of Environmental Conservation, Albany, New York. Report No. RAD-P3 (11/82).

38. Durham, R. W., S. Livermore, E. A. Kokotich, and J. A. Fitzgerald, "Great Lakes Radiological Surveillance - 1981," National Water Research Institute, Environment Canada, Burlington, Ontario, 1982.

39. Data provided by D. P. Meyerhof, Department of National Health and Welfare, Ottawa, April 28, 1983.

40. "Environmental Radiation Data," Report 25-26, Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C., October 1981.

41. "Environmental Radiation Data," Report 27, Office of Radiation Program, U.S. Environmental Protection Agency, Washington, D.C., December 1981.

42. "Environmental Radiation Data," Report 28, Office of Radiation Program, U.S. Environmental Protection Agency, Washington, D.C., September 1982.

43. Data provided G. W. Bruchmann, Michigan Department of Public Health, Lansing, Michigan, April 26, 1983.

44. Data provided by L. J. McDonnell, Wisconsin Department of Health and Social Services, Madison, Wisconsin, June 21, 1983.

45. Data provided by J. C. Corpuz, Indiana State Board of Health, Indianapolis, Indiana, February 18, 1983.

46. Data provided by F. J. Melchiorri, Illinois Department of Nuclear Safety, Springfield, Illinois, March 1, 1983.

47. Data provided by A. Hayton, Ontario Ministry of the Environment, Toronto, Ontario, May 24, July 18, and July 25, 1983.

48. Flow data provided by Environmental Conservation Service, Environment Canada, Guelph, Ontario.

49. "Great Lakes Water Quality, 1975," Appendix D, Annual Report of the Radioactivity Subcommittee, Great Lakes Water Quality Board, International Joint Commission, Windsor, June 1976.

50. "Great Lakes Water Quality, 1976", Appendix D, Annual Report of the Radioactivity Subcommittee, Great Lakes Water Quality Board, International Joint Commission, Windsor, July 1977.

51. "Environmental Radiation Data," Report 23-24, Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C., April 1981.

52. "Long-Term Management of Liquid High-Level Radioactive Wastes Stored At The Western New York Nuclear Service Center, West Valley." Final Environmental Impact Statement, U.S. Department of Energy, Washington, D.C., June 1982. Report No. DOE/EIS-0081.

53. "Long-Term Management of Liquid High-Level Radioactive Waste at the Western New York Nuclear Service Center, West Valley. Record of Decision," U.S. Department of Energy, Washington, D.C., September 16, 1982.

54. "Analysis of the Terminal Waste Form Selection for the West Valley Demonstration Project," West Valley Demonstration Project, West Valley, New York, June 1983. Report No. WVDP-100.

55. "Annual Report, Fiscal Year 1982," West Valley Demonstration Project, West Valley, New York.

56. "Radioactive Waste Management in Canada: AECL Publications and Other Literature," AECL-6186, Rev. 3, 1983. Available from AECL, Scientific Document Distribution Office, Chalk River, Ontario K0J 1J0.

57. Proceedings of International Conference on Radioactive Waste Management," held September 12-15, 1982 in Winnipeg, Manitoba. Available from the Canadian Nuclear Society, Toronto, Ontario M5G 1P7.

58. "Environmental Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Draft Environmental Impact Statement for 40 CFR 191, U.S. Environmental Protection Agency, Washington, D.C., December 1982. Report No. EPA 520/1-82-025.

59. "Environmental Pathway Models for Estimating Population Health Effects from Disposal of High-Level Radioactive Waste in Geologic Repositories," Draft Report, U.S. Environmental Protection Agency, Washington, D.C., December 1982. Report No. EPA-520/5-80-002.

60. "A Study of the Isolation System for Geologic Disposal of Radioactive Wastes." National Academy Press, Washington, D.C., 1983.

61. Nature, Vol. 303, May 26, 1983, p. 275.

62. Electrical World, October 1981, pp. 25-27.

63. Press release No. 82-47, from U.S. Nuclear Regulatory Commission, Glen Ellyn, Illinois, May 20, 1982.

64. "Integrated Plant Safety Assessments, Systematic Evaluation Program - Palisades Plant," U.S. NRC Draft Report, Washington, D.C., April 1982. NUREG-0820.

65. Press release, No. I-82-85, from U.S. Nuclear Regulatory Commission, King of Prussia, Pennsylvania, August 23, 1982.

66. "Integrated Plant Safety Assessment, Systematic Evaluation Program, R. E. Ginna Nuclear Power Plant". U.S. NRC Draft Report, Washington, D.C., May 1982. NUREG-0821.

67. "Canadian Drinking Water Standards and Objectives, 1968", The Joint Committee on Drinking Water Standards, The Advisory Committee on Public Health Engineering and the Canadian Public Health Association, published by the Department of National Health and Welfare, Ottawa, October 1969.

68. "Globe and Mail", September 7, 1983.

69. Personal communication on August 5, 1983 from R. M. Chatterjee, Atomic Energy Control Board, Ottawa, to M. P. Bratzel, Jr., International Joint Commission, Windsor.

70. "Report on ICRP Committee II on Permissible Dose for Internal Radiation (1959), with Bibliography for Biological, Mathematical and Physical Data." Health Physics, Vol. 3, 1959, pp. 1-380.

71. "Recommendations of the International Commission on Radiological Protection", ICRP Publication 6, International Commission on Radiological Protection, Pergamon Press, Oxford, 1964.

72. "Alkaline Earth Metabolism in Adult Man", ICRP Publication 20, International Commission on Radiological Protection, Pergamon Press, Oxford, 1972.

73. "Recommendations of the International Commission on Radiological Protection", ICRP Publication 9, International Commission on Radiological Protection, Pergamon Press, Oxford, 1966.

74. Material provided by D. P. Meyerhof, Canada Department of National Health and Welfare, Ottawa, through a personal communication dated August 17, 1983 to M. P. Bratzel, Jr., International Joint Commission, Windsor, Ontario.

75. Durham, R. W. Unpublished data, provided in a personal communication dated August 16, 1983 to M. P. Bratzel, Jr., International Joint Commission, Windsor, Ontario.

76. Data provided by K. Rimawi, New York Department of Health, Albany, New York, August 1, 1983.

77. "Environmental Radiation Data", Report 29, Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C., June 1982. Report No. EPA 520/5-83-005.

78. "Environmental Radiation Data", Report 30, Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C., September 1982. Report No. EPA 520/5-6-83-006.

79. Information provided by L. K. Cohen, U.S. Nuclear Regulatory Commission, Washington, D.C., July 22, 1983.

80. "NRC Program for the Resolution of Generic Issues Related to Nuclear Power Plants", U.S. Nuclear Regulatory Commission, Washington, D.C., January 1978. Report No. NUREG-0410.

81. "Identification of Unresolved Safety Issues Relating to Nuclear Power Plants", U.S. Nuclear Regulatory Commission, Washington, D.C., January 1979. Report No. NUREG-0510.

82. "Identification of New Unresolved Safety Issues Relating to Nuclear Power Plants", U.S. Nuclear Regulatory Commission, Washington, D.C., March 1981. Report No. NUREG-0705.

83. "1982 NRC Annual Report", U.S. Nuclear Regulatory Commission, Washington, D.C.

84. "NRC Action Plan Developed as a Result of the TMI-2 Accident", Volumes 1 and 2, U.S. Nuclear Regulatory Commission, Washington, D.C., May 1980. Report No. NUREG-0660.

85. "Clarification of TMI Action Plan Requirements", U.S. Nuclear Regulatory Commission, Washington, D.C., October 31, 1980. Report No. NUREG-0737.

86. Tracy, B. L. and F. A. Prantl, "25 Years of Fission Product Input to Lakes Superior and Huron." Water, Air, and Soil Pollution, Vol. 19, 1983, pp. 15-27.

87. Information provided by S. Llewellyn, Canada Department of the Environment, Toronto, through a personal communication dated September 28, 1983 to M. P. Bratzel, Jr., International Joint Commission, Windsor, Ontario.

88. Information provided by M. Goffin, Canada Department of the Environment, Toronto, through a personal communication dated October 24, 1983 to M. P. Bratzel, Jr., International Joint Commission, Windsor, Ontario.

89. Information provided by C. Létourneau, Atomic Energy Control Board, Ottawa, through a personal communication on October 6, 1983 to M. P. Bratzel, Jr., International Joint Commission, Windsor, Ontario.

90. "Annual Summary of Radiological Data for 1979". Ontario Hydro, Pickering, Ontario, 1980. Report No. SSD-AR-79.

91. "Energy Analects", Vol. 12, No. 36, September 16, 1983, p. 4.

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